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FOR REVIEW.

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The Call, San Francisco, California.
The Chronicle, San Francisco, California.
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The Mercury, San Jose, California.
The Record-Union, Sacramento, California.
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MOUNTAIN SITES FOR OBSERVATORIES.

By A. G. McAdie.

The establishment of the Lick Observatory marked an epoch in astrophysical work in more ways than one. The selection of a high-level site on the Pacific Coast, where it was anticipated favorable atmospheric conditions would prevail, was a recognition of the importance of conducting future research under different conditions than those experienced by the great observatories of the world — situated at low levels and near centers of population. The establishment of observatories in South America, and within the past few years the inauguration of the Solar Physics Observatory at Mt. Wilson, Cal. (elevation about 6,000 feet), are but progressive developments along the line. In brief, it is now clearly recognized that work must be carried on where there is the greatest possible freedom from the atmospheric disturbances so common at low levels. Primarily the question of definition is all important, and there is little reason to doubt that in any observatory and almost in any line of work, the greatest possible improvement will be accomplished by securing the best possible definition. Unfortunately, instruments must be located upon the ground and not in the free air. It follows therefore that the astronomer is handicapped at the very outset by the instability of the lowermost air stratum—the air close to the ground. The tremulous character of air near the ground during both day and night hours materially affects the definition. If we stop to consider the loss and gain of heat in this level, we need not be surprised at the existence of marked convectional currents and stream lines, all tending to distort the wave-front and prevent perfect definition. Where day observing is necessary, as in solar work, we have a steadily increasing instability, due to the Sun's altitude, and all the unequal warming effects, due to radiation, convection, and conduction. One anticipates therefore that the best seeing is, as a rule, during the early morning hours; or when the atmosphere is nearly quiet and there is a minimum amount of dust or haze. At night the

air near the Earth's surface is disturbed by cooling, due to radiation, and by warming, due to air motion and absorption of heat from other strata. The surface of the Earth is itself losing heat by radiation and receiving heat by slow conduction from the lower earth. Furthermore, the presence of water-vapor materially alters the heat distribution, since we have the latent heat of condensation set free during the cooling; and, conversely, a large amount of heat utilized in vaporizing water during the warming process. Nor is the radiation by gaseous matter the same as from the ground or water surfaces. In the former every particle radiates into space directly, whereas with the solid or liquid only a surface radiation occurs. Evidently then the problem is a complicated one; one in which we have to deal not only with the nocturnal cooling and diurnal warming of the Earth's surface, but also the cooling and warming of the atmosphere. Recent experiments indicate that there is at times well-marked stratification of the air and surfaces of discontinuity. This was shown to be possible by HERMANN VON HELMHOLTZ[1], in the formation of fog billows, where atmospheric strata of different density and temperature lie contiguous; and has been confirmed by recent determinations with kites and balloons. The *isothermal layer* which has just been discovered—a level at which there is a cessation of temperature distribution—is probably due to the absence of vertical convection, and is especially significant as indicating that the absorbing power of the atmosphere becomes a minimum chiefly because of the small quantity of water-vapor present at that height. To astronomers the existence of this isothermal layer is, as pointed out by Professor TURNER,[2] especially interesting in connection with atmospheric refraction. Assumptions heretofore made in connection with refraction no longer hold.

This isothermal level, however, is far beyond our reach. Its height is approximately 12,000 meters. What we are most concerned about at the present time is "good seeing," if attainable within a short distance above the ground. While what precedes shows that the full solution is not restricted to the layers of air next the ground, it has been found by LANGLEY,

[1] Paper published in 1888, Royal Prussian Academy of Sciences; translated by ABBE, Smithsonian Institution, 1891.

[2] Section A, British Association Dublin Meeting. See *Nature*, October 1, 1908, p. 550.

HALE, ABBOT, and others, that within a height of one hundred feet above the ground material improvement can be had by, (1) having the telescope as high as possible above the ground,[1] and (2) by churning the column of air in the tube of the telescope (LANGLEY and ABBOT). The result of these innovations is to thoroughly mix the air and prevent the formation of layers of different density; also, preventing any undue heating of mirrors or of tubes. To some extent "boiling" can thus be eliminated. HALE proposes to further reduce the "heating effect by doing away with the tube and using shelter houses with canvas louvres, permitting free circulation of air, but shielding from direct insolation and radiation.

From all that precedes, then, it is evident that while perfect conditions need not be expected, considerable improvement is possible in the efficiency of observatories, both in the details of work and in the increased working hours, if future observatories are located at high levels, where cloudless, dry, dust-free, haze-free, and homogeneous atmospheric conditions prevail. It is not too much to say that, except for what may be called the general routine work of an observatory, present institutions at low levels have reached the limit of their efficiency. It would be unwise to equip such observatories with the powerful instruments of modern astrophysical research. HALE puts the case fairly when he says:—[2]

> "Even if the means were available for supplying the necessary instruments to existing observatories, they could not be successfully employed without atmospheric conditions much superior to those at present available."

There is one other aspect to be considered. Much astrophysical work to-day is concerned with the absorption and radiation of energy in the atmospheres of the Sun, the stars, and the planets. For example, ABBOT[3] shows that from

> ". . . the combined work of RUBENS, ASCHKINASS, LANGLEY, KEELER and VERY, NICHOLS (and his own) a tenth part of the average amount of water-vapor in the vertical column of atmosphere above sea-level is enough to absorb more than half of the radiation of the Earth through space, etc., and that the real surface which communicates the Earth's heat through

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[1] See HALE, "Study of Conditions for Solar Research at Mt. Wilson, Cal., 1905," p. 170.

[2] "Solar Researches at Mt. Wilson," pp. 159.

[3] *Annals of the Astrophysical Observatory*, p. 172.

space is the water-vapor and carbonic acid layer lying perhaps 4,000 meters above sea-level."

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No one recognized more clearly than Professor LANGLEY the importance of good seeing.[1] No one foresaw the necessity of high-level observatories in determining the true value of the solar constant in determinations of variability of solar radiation. As early as 1881 he proved the value of experimental work at a high level on the Pacific Coast, in a region less exposed to storm and with an atmosphere immeasurably superior, so far as the absence of dust and water-vapor are concerned, to any attainable elsewhere in our country. His classic researches on Mt. Whitney and Lone Pine should be repeated at the same points for many reasons. The value of the solar constant thus redetermined would approximate 2.1 calories per square centimeter per minute, and such a determination would be authoritative.

Mt. Whitney is to-day more accessible than when Professor LANGLEY made his experiments. It is believed that there are excellent localities close by at which temporary observatories could be erected. And what is true of this section of the High Sierra holds for other mountains on the Pacific Slope. In some ways the Sierra Madre are to be preferred, owing to the general condition of air steadiness; but it may be that for purposes which do not now appear sites in the northern ranges, extending perhaps to the Cascades, would be advantageous.

While the writer does not claim any special knowledge concerning availability of different sites in the mountains of the Pacific Slope, it so happens that he has made the ascent of and measured the three highest peaks on the Pacific Coast, excluding peaks in Alaska. These are Mt. Whitney, 14,502 feet; Mt. Shasta, 14,200 feet; and Mt. Rainier, 14,394 feet.

As the various data obtained on these ascents are not readily accessible, I give the following results of our observations, and some other general information:—

MT. WHITNEY, CALIFORNIA.

This peak is situated in latitude 36° 34′ 33″ N., and longitude 118° 17′ 32″ W.

[1] *American Journal of Science*, 1903, p. 89.

References: LANGLEY, "Researches on Solar Heat"; Professional Paper No. 15, Signal Service, 1884; WHEELER, "Surveys West of the 100th Meridian, 1889"; STEWART, *Mount Whitney Club Journal,* Visalia, Cal.; LE CONTE, *Sierra Club Bulletin;* MCADIE, *Sierra Club Bulletin,* June, 1904; and *Monthly Weather Review,* 1903.

The mountain can be reached in several ways; from Lone Pine on the Carson and Colorado Railroad; by trail from Kern River to Langley's Camp, 3,000 feet below the summit; and from the northern end of the Kern River. A good climber can go from Langley's Camp to the summit in less than four hours.

On September 2 to 6, 1881, Professor LANGLEY made eighteen simultaneous observations at Lone Pine and Mt. Whitney. The means of the eighteen observations for pressure and temperature are as follows:—

Lone Pine.

Pressure	26.018 inches	$660^{mm}.9$
Temperature	69°.6	20°.9 C.

Mt. Whitney.

Pressure	17.586 inches	$446^{mm}.6$
Temperature	37°.2	2°.9 C.

MCADIE and LE CONTE obtained a mean pressure from eight readings, corrected for tempearture, scale, capillarity, and gravity, of 17.694 inches ($449^{mm}.4$) at the summit of Mt. Whitney, and mean temperature of 52° F. (11°.1 C.).

Various wet-bulb readings have been obtained by LANGLEY, WHEELER, CAMPBELL, and ABBOT, all showing extreme dryness, and relative humidity varying from ten to twenty per cent.

HALLECK, with a temperature of 34° F. (1°.1 C.), determined boiling-point to be 186°.4 F. (86° C.). HUTCHINGS reports the boiling-point at 187° F.

MT. RAINIER, WASHINGTON.

This peak is a volcanic cone, situated in latitude 46° 51′ 5″ N., and longitude 121° 45′ 28″ W.

References: BAILEY WILLIS, U. S. Geological Survey papers; *Mazama Club Bulletin,* Portland, 1905-6; *Sierra Club Bulletin,* 1905.

The mountain can be climbed from different sides, but probably the safest and easiest way is from Ashford, via Longmyers, to Paradise Valley.

On July 25, 1905, the following observations were made by A. G. McAdie and checked by Professor J. N. Le Conte:—

Mercurial barometers, Green Standard No. 1664 and No. 1554. Four readings, at Columbia Crest, summit of Mt. Rainier; mean pressure corrected for temperature, instrumental error, and gravity, 17.663 inches, $448^{mm}.6$. Mean temperature at summit, 39° F. (3°.9 C.); mean temperature of air column from readings at summit and sea-level, 50° F. (10° C.). The sea-level pressure reading, mean of Tacoma, Seattle, Portland, and Spokane, was 29.960 inches. The height, as determined by us, 14,394 feet (4,387 meters).

The boiling-point, as determined on the south rim of the crater, probably thirty meters below the true summit, was 187°.4 F. (86°.4 C.).

A sling psychrometer gave the following temperatures:—

Dry bulb,	37° F.,	36°.4,	36°.5,	36°.5,	37°.0,	mean 36°.7 F.
Wet bulb,	32	28 .0,	25 .0,	24 .2,	25 .5,	mean 26 .9

The dew-point was approximately 10°; the vapor pressure, 0.07 of an inch; relative humidity, thirteen per cent.

MT. SHASTA, CALIFORNIA.

This peak is situated in latitude 41° 24′ 28″ N., and longitude 122° 11′ 49″ W.

The following observations were made on the summit of Mt. Shasta on August 5, 1905:—

Six pressure readings. Mean pressure, corrected for temperature, instrumental error, and gravity, 17.993 inches; mean temperature of air column, 60° F.

The height, as determined by us, 14,200 feet (4,329 meters). The boiling-point at the summit, as then determined, 187°.7 F. (86°.5 C.).

In our work we fully recognize that the mean temperature of the column of air is a very uncertain quantity. The air is seldom in rest. On the dates of our ascents we noted marked stratification. Above the 10,000-foot level (3,048 meters) the drift of the air appeared to be entirely different from the motion of the lower levels.

ASTRONOMICAL OBSERVATIONS IN 1908.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris*.[1]

Jan.	2:	S { > e. < d.
	4:	id.
	5:	< d.
	10:	1 step < d.
	13:	= d.
	14:	id.
	18:	id.
	20:	id.
	21:	id.
	28:	id.
	29:	id.
	31:	id.
Feb.	2:	1 step > d.
	6:	2 steps > d.
	8:	id.
	10:	id.
	16:	id.
	19:	{ in the midst between d and c.
	23:	2½ steps > d.
	29:	{ in the midst between d and e.
Mar.	23:	1 step > e.
	24:	= e.
	25:	1 step < e.
	26:	id.
	27:	id.
	28:	2 steps < e.
	29:	id.
	30:	3 steps < e.
Apr.	1:	4 steps < e.
	2:	3 steps > f.
	3:	id.
	6:	id.
	7:	id.
Apr.	8:	id.
	19:	1 step > f.
May	1:	= f.
	11:	= g.
	18:	{ < g. > h.
	20:	id.
Aug.	14:	1 step > d.
	17:	2 steps > d.
	23:	id.
	24:	id.
	27:	id.
	29:	1 step > d.
	31:	2½ steps > d.
Sept.	3:	3 steps > d.
	9:	id.
	16:	5 steps > d.
	19:	6 steps < c.
	22:	5 steps < c.
	24:	id.
	25:	id.
	30:	5 steps > d.
Oct.	3:	id.
	5:	id.
	10:	4 steps > d.
	18:	1 step < d.
	22:	2 steps > d.
Nov.	1:	= e.
	6:	id.
	8:	id.
	16:	{ in the midst between e and f′.
	26:	2 steps > f.
	29:	{ < f. > g.

[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.

T *Ursæ Majoris.*[1]

Jan.	2:	T 5 steps > a.
	4:	4 steps > a.
	5:	id.
	10:	2 steps > a.
	13:	1 step > a.
	14:	id.
	18:	2 steps > a.
	20:	1½ step > a.
	21:	2 steps > a.
	28:	1 step < a.
	29:	id.
	31:	id.
Feb.	2:	2 steps < a.
	6:	< b. > c.
	8:	1 step < b.
	9:	id.
	10:	2 steps > c.
	16:	id.
	19:	in the midst between c and d.
	23:	1½ step > d.
	29:	in the midst between d and e.
Mar.	18:	< e.
	23:	= f.
	24:	< f. > g.
	25:	id.
	26:	1 step > g.
	27:	= g.
	28:	id.
	29:	1 step < g.
	30:	id.
Apr.	1:	very faint.
	2:	id.
	3:	id.
	6:	id.
	7:	id.

Apr.	8:	invisible.
	15:	id.
	16:	id.
	19:	id.
	20:	id.
May	11:	id.
	18:	id.
	20:	id.
Aug.	14:	< b. > c.
	17:	1 step > b.
	23:	< a. 2 steps > b.
	24:	< a. > b.
	27:	1 step > a.
	29:	2 steps > a.
	31:	1 step > a.
Sept.	3:	2 steps > a.
	9:	3 steps > a.
	16:	id.
	19:	4 steps > a.
	22:	id.
	24:	id.
	25:	id.
	30:	= a.
Oct.	3:	id.
	5:	= b.
	10:	id.
	18:	= c. (?)
	22:	< c. > d.
Nov.	1:	1 step < d.
	4:	3 steps > e.
	6:	id.
	8:	id.
	16:	id.
	26:	= g.
	29:	= f = g.

The comparison stars f and g are found to be a little variable. August 24th, I have noted: g 1 step > f. On November 29th: f = g. Usually I note: f > g, the difference being only 1 step. B. D. has f = g = $9^m.5$; Harvard has f = $10^m.75$, g = $10^m.40$.

[1] Vide the sketch in the *Publications A. S. P.*, No. 22, 4, 63.

W *Pegasi.*[1]

Jan.	1:	W = b.
	2:	in the midst between b and c.
	4:	$<$ b. $>$ c.
	5:	id.
	14:	1 step $>$ c.
	18:	= c.
	20:	id.
	21:	1 step $<$ c.
	29:	3 steps $<$ c.
	31:	1 step $>$ d.
Feb.	2:	1½ step $>$ d.
	9:	1 step $>$ d.
	19:	= e.
	29:	in the midst between e and f.
Aug.	14:	$<$ g. $>$ h.
	18:	= h.
	23:	id.

Aug.	24:	id.
	27:	$<$ g. $>$ h.
	29:	id.
	31:	id.
Sept.	3:	id.
	4:	id.
	12:	id.
	16:	a little $>$ h.
	20:	$<$ g. $>$ h.
	24:	= g.
	25:	= f.
	30:	id.
Oct.	3:	1 step $<$ f.
	5:	id.
	18:	1 step $<$ e.
Nov.	8:	2 steps $<$ c.
	16:	1 step $<$ b.
	26:	= b.
	29:	id.

SS *Cygni.*[2]

Jan.	1, 6^h:	SS = g.
	2, 9^h:	$<$ g.
	4, 6^h:	= h.
	5, 7^h:	very faint.
	14, 6^h:	invisible.
	18, 6^h:	id.
	20, 6^h:	id.
	21, 7^h:	id.
	29, 7^h:	1 step $<$ b.
	31, 7^h:	= b.
Feb.	2, 7^h:	$<$ b. 2 steps $>$ c.
	6, 6^h:	2 steps $>$ d.
	9, 6^h:	= e.
	16, 7^h:	invisible.
	19, 7^h:	very faint.
Apr.	20, 12^h:	invisible.
	21, 10^h:	id.
	26, 11^h:	id.
May	1, 11^h:	1 step $<$ e.
	9, 10^h:	1 step $<$ c.

May	11, 11^h:	3 steps $>$ c. 1 step $<$ b.
	15, 10^h:	1 step $>$ c.
	18, 11^h:	1 step $<$ c.
	20, 12^h:	= d.
Aug.	14, 10^h:	$>$ e. $<$ d.
	15, 10^h:	in the midst bet. d and e.
	17, 11^h:	$<$ e.
	18, 10^h:	4 steps $<$ e.
	23, 10^h:	= f.
	24, 10^h:	$>$ f. $<$ e.
	27, 10^h:	1 step $>$ f.
	29, 10^h:	$>$ f. $<$ e.
	31, 10^h:	= e.
Sept.	3, 10^h:	= e.
	4, 9^h:	$>$ f. $<$ e.

[1] Vide the sketch in the *Publications A. S. P.*, No. 60, **10**, 23.
[2] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 18.

Sept.	9, 9^h:	= d.
	11, 8^h:	2 steps < c.
	12, 8^h:	1½ step < c.
	16, 9^h:	2 steps > c.
	19, 9^h:	in the midst bet. b and c.
	20, 8^h:	b(3)SS(2)c
	23, 8^h:	< c. > d.
	24, 10^h:	= d.
	25, 9^h:	2 steps < d.
	30, 12^h:	4 steps < d.
Oct.	1, 10^h:	id.
	3, 9^h:	= e.
Oct.	5, 8^h:	< d'. > e.
	18, 9^h:	d'(3)SS(2)e
Nov.	1, 8^h:	< d'. > e.
	4, 8^h:	= e.
	6, 9^h:	= e(?).
	8, 7^h:	d'(3)SS(2)e
	14, 7^h:	2 steps > c.
	16, 8^h:	= d.
	26, 6^h:	= e.
	29, 6^h:	1 step > f.

Z *Cygni*.[1]

Jan.	1:	Z 2 steps > a.
	2:	1 step > a.
	4:	< a.
	5:	< a. > b.
	14:	1 step > a.
	18:	2 steps > a.
	20:	1 step > a.
	21:	id.
	28:	= a.
	29:	2 steps > a.
	31:	1 step > a.
Feb.	2:	= a.
	6:	= b.
	16:	2 steps > b(?).
	19:	= b.
Mar.	25:	very faint.
Apr.	1:	id.
	20:	invisible.
	21:	id.
	26:	very faint.
May	1:	faint, < e.
	9:	invisible.
	15:	id.
	18:	id.
	20:	id.
Aug.	14:	id.
	18:	id.
	23:	id.
Sept.	3:	= e.
	9:	> e. < d.
	11:	> d. < c.
	16:	id.
	19:	= d.
	22:	> c. < b.
	24:	id.
	30:	= b.
Oct.	3:	= b'.
	5:	id.
	18:	< a. > b'.
Nov.	1:	= b'.
	4:	= b.
	6:	1 step > b.
	8:	1½ step < b.
	14:	1 step < b.
	16:	< b. > c.
	29:	= d.

Y *Tauri* (B. D. + 20° 1083).

A number of forty comparisons have been made upon this irregular variable star, which during the whole year was either

[1] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 16.

equal to or some steps brighter than the star A = B. D. + 20° 1095 ($7^m.4$). In February, March, and April the star Y had reached its maximum ($7^m.1$), but in January and November it had decreased a few steps.

U *Herculis.*

Apr. 20:	U invisible(?).	Sept. 11:	$\left\{ \begin{matrix} < c. \\ > d. \end{matrix} \right.$
26:	2 steps < h.	12:	= c.
May 1:	id.	16:	$\left\{ \begin{matrix} < c. \\ > d. \end{matrix} \right.$
18:	1 step > h.	19:	C(2)U(3)d.
20:	id.	22:	id.
Aug. 15:	= a.	23:	$\left\{ \begin{matrix} \text{in the midst} \\ \text{between c and d.} \end{matrix} \right.$
17:	$\left\{ \begin{matrix} > c \\ < a \end{matrix} \right\}$ b > a.	24:	id.
18:	2 steps < a.	25:	C(3)U(2)d.
23:	id.	30:	id.
24:	id.	Oct. 3:	= d.
27:	id.	5:	2 steps > d.
29:	id.	10:	1 step > d.
31:	= c.	18:	= e.
Sept. 3:	id.	Nov. 29:	2 steps < f.
4:	1 step > c.		
9:	½ step > c.		

I have used the sketch in the *Publications A. S. P.*, No. 106, **18**, 52, drawn by Miss Rose O'Halloran, but have added the two small neighboring stars g at a and h at f, both northward.

A Suspected Variable Star.

138.1908 *Herculis.*

During my observations upon U *Herculis* my attention was directed to the two comparison-stars,

a = B. D. + 19° 3096 $7^m.0$.
b = B. D. + 19° 3089 $7^m.8$.

The star b is here eight steps fainter than a. On August 5, 1907, I found b > a, and so I have seen it until October, 1908. On October 5th, 10th, and 18th, I have noted: b 2-3 steps < a. But when the ocular was screwed out the reddish star a was "diminished," and then seemed to be equal to or even dimmer than b. In A. G. Berlin A 5856 is

a = $7^m.2$
b = $7^m.7$,

and in *Harvard Annals,* **37**, 170 and 183, we find

$$a = 7^{m}.36$$
$$b = 7^{m}.39.$$

Whether the variable is a or b is still difficult to decide. According to its red color, it might perhaps be the star a, though a look at the differences might point out b as the variable one. It will be necessary to compare b with a and c. (Vide *Astronomische Nachrichten,* No. 4274, **179**, 29.)

Meteors.

Fireballs have been observed from stations in Denmark at the following dates: January 3d, 21st; March 2d, 16th, 25th; April 8th, 15th; May 1st, 11th, 29th; June 25th, 26th; July 2d, 20th, 21st; August 6th, 20th; October 7th, 24th; November 8th, 21st; December 3d, 7th.

Shooting-Stars.

A little swarm of shooting-stars, during five minutes more than thirty meteors, was observed on January 2d, $8^{h}\ 10^{m}$–$8^{h}\ 20^{m}$, at Hjörring, Denmark, radiant $= 300° + 61°$; and on January 3d, $11^{h}\ 23^{m}$–$12^{h}\ 42^{m}$, seventeen large shooting-stars were mapped at Paderborn, Germany. (Vide *Astronomische Rundschau,* No. 98, and *Astronomische Nachrichten,* No. 4263, **178**, 255.) On June 25th, $10^{h}\ 30^{m}$, an observer at Odense, Denmark, mapped a most interesting twin-meteor, two shooting-stars with parallel paths, with a distance of ½°, one on each side of the pretty star *Arcturus*.

The weather was, in the year 1908, quite unfavorable for the planned observations on shooting-stars in August, and after November 29th the sky was overcast with clouds every night here at Odder.

The above-mentioned estimations of variable stars have often been controlled by my young assistant, Jörgen Fog.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1909.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon....	Mar. 6,	$6^h\ 56^m$ P.M.	Full Moon....	April	5,	$12^h\ 28^m$ P.M.
Last Quarter..	" 14,	7 42 P.M.	Last Quarter..	"	13,	6 30 A.M.
New Moon....	" 21,	12 11 P.M.	New Moon....	"	19,	8 51 P.M.
First Quarter..	" 28,	8 49 A.M.	First Quarter..	"	27,	12 36 A.M.

The vernal equinox, the time when the Sun crosses the equator from south to north, occurs March 20th, 10 P.M., Pacific time.

Mercury is a morning star on March 1st, and continues to be such until April 21st. It then passes superior conjunction with the Sun and becomes an evening star. Greatest west elongation is passed on March 9th. The planet's apparent distance from the Sun is 27° 26′. This is greater by 9° than the greatest east elongation in January, and is due to the circumstance that the time of perihelion passage was about the same as the January east elongation, while the March west elongation occurs within a week of aphelion time. Conditions for visibility of *Mercury* as a morning star during the spring months are seldom good, but for this year the planet will rise more than an hour before sunrise during the first two weeks of March, and it can be seen as a morning star nearly as well as it could be seen as an evening star in January. After passing superior conjunction, on April 21st, it moves rapidly away from the Sun, and by the end of the month it sets nearly an hour after sunset. *Mercury* is in close conjunction with *Saturn* on April 13th and with *Venus* on April 19th, but the planets are then too near the Sun for naked-eye view.

Venus is a morning star on March 1st, and remains such until April 28th. It then passes superior conjunction with the Sun and becomes an evening star. On March 1st it is only about 14° away from the Sun and is at the same time about 7° south of that body; so it rises only a trifle more than

half an hour before sunrise, and it will scarcely be possible to see it; although the greater brightness of *Venus*, even when at its greatest distance from us, as it is at superior conjunction, makes it a much easier object than *Mercury*, when they are at the same apparent distance from the Sun. After the opening days of March it will certainly be too near the Sun for naked-eye visibility until some time after it becomes an evening star.

Mars rises a little after 3^h A.M. on March 1st, and at about 1^h 40^m A.M. on April 30th. It moves, during the two months, about 43° eastward and 5° northward from a position in *Sagittarius* north of the handle of "the milk-dipper" group to the eastern part of *Capricorn*. No very bright stars are near its path. Its distance from the Earth is still rapidly diminishing from 151,000,000 miles on March 1st to 104,-000,000 miles on April 30th, and there is a consequent increase in brightness of a little more than one hundred per cent during the two months' period. At the end of April, however, it is still nearly three times as far away from us as it will be at the time of opposition in September, and only about one ninth as bright. On the afternoon of March 26th it is in conjunction with *Uranus*, passing only 18′, a little more than one half of the Moon's apparent diameter, to the south. For a day or two before and after conjunction the planets will be near together.

Jupiter was in opposition to the Sun on the last day of February. It is therefore above the horizon practically the entire night during early March. By the end of April it rises early in the afternoon and sets at about 2^h 30^m A.M. It continues to retrograde,—that is, move westward,—not quite 5° during the two months, and 2° northward, toward *Regulus*, *α Leonis*, and at the end of April is only about 6° east of that star. Toward the close of April the westward motion becomes very slow, and it ceases on May 1st. After that date the planet resumes its general eastward motion.

Saturn is an evening star on March 1st, setting a little more than two hours after sunset. The Sun in its eastward motion among the stars rapidly overtakes the planet and passes it on the morning of April 3d. The planet then becomes a morning star and lags behind the Sun, so that by the end of the month it rises nearly an hour before sunrise. During a con-

siderable part of the two months' period *Saturn* is too near the Sun for naked-eye observation.

Uranus rises shortly after 4^h A.M. on March 1st, and shortly after midnight on April 30th. It is in the constellation *Sagittarius* and moves a fraction of a degree eastward until April 25th, when it becomes stationary. Its conjunction with *Mars* on March 26th has been noted.

Neptune is nearly stationary in *Gemini*.

EIGHTH AWARD OF THE BRUCE MEDAL.

At a meeting of the Board of Directors of the Astronomical Society of the Pacific, held on November 28, 1908, the Bruce Gold Medal of the Society was awarded to Doctor George W. Hill, of West Nyack, New York, for distinguished services to astronomy. The presidential address, reviewing the life and works of the eighth recipient of this medal, will be delivered at the annual meeting of the Society, to be held in San Francisco on March 27th.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE FRANK P. BRACKETT OBSERVATORY OF POMONA COLLEGE, CLAREMONT, CALIFORNIA.

Pomona College has recently dedicated a new observatory. The building was presented by Mr. LLEWELLYN BIXBY, an alumnus of the college, and named for a former teacher, now the director of the observatory. It is a small building, designed primarily for student work. It contains a six-inch equatorial with Clark objective and Gaertner mounting; a three-inch transit and a chronograph, also made by Mr. GAERTNER; and a Riefler mean-time clock. A smaller laboratory clock will be used for sidereal time until another Riefler clock can be purchased.

A horizontal solar telescope, with six-inch objective and a focal length of forty feet, is nearly completed. This is to be used with a spectrograph of the Littrow type, having a focal length of fifteen feet. The cœlostat has two mirrors—one, a flat mirror ten inches in diameter, is driven by clock-work so as to reflect the light from the Sun upon the second; also a flat mirror twelve inches in diameter, which is mounted with alt-azimuth motion on a column just south of the first. From this mirror the light passes through the objective which is mounted on a pier north of the cœlostat. The cœlostat was built by Mr. GAERTNER, its mirrors and the objectives of both telescope and spectrograph being made by M. PETITDIDIER, of Chicago.

The cœlostat and objective of the horizontal telescope rest upon a concrete foundation and are covered by a small house which runs upon a track, so that it can be entirely removed when the instrument is in use. This house is connected with the main building by a pergola, which will be covered with vines to shelter the beam of light in its passage from the

objective to the slit. The slit of the spectrograph and the plate-holders are placed in the focal plane of the forty-foot objective, upon a concrete pier in the observatory, near the south side. The grating and the lens, which serves as both collimator and camera lens, are mounted upon another pier fifteen feet north of the first.

The building is made of stone and stands on a slight elevation in the park, well removed from other buildings and from ordinary travel. A flat roof or deck floor covers the building, except the central portion where the dome-room stands. This deck, protected by the parapet which crowns the walls, affords a good place for direct observation of the sky.

The opening of the observatory was the occasion of a notable address by Dr. George E. Hale, Director of the Mt. Wilson Solar Observatory, announcing some important discoveries recently made at Mt. Wilson concerning the vortical character of sun-spots.

Visibility of Mt. Whitney from Mt. Hamilton.

It has been the tradition at Lick Observatory that Mt. Whitney could not be seen from Mt. Hamilton because of an intervening mountain.

A year or two ago, when the air was unusually clear after some of the winter storms, the Sierras could be traced almost to their extreme southern end. A coffin-shaped peak was noticed then which looked very much as the pictures of Mt. Whitney would lead one to expect. So striking was the resemblance that the bearing of Mt. Whitney from Mt. Hamilton was determined from their known geographical positions.

Just recently the Sierras were exceptionally clear and the same peak was visible, as well as the outlines of a nearer dark range projected against the snow of the more distant range. The bearing of the peak supposed to be Whitney was measured with a surveyor's transit. Following are the computed and observed directions:—

Computed bearing of Mt. Whitney from Lick Observatory, main building—16° 28′ south of east.

Observed bearing of Mt. Whitney from Lick Observatory, main building—16° 30′ south of east.

Distance, 191 miles.

An examination of the topographical maps of that region, published by the U. S. Geological Survey, shows that about ten miles this side of Mt. Whitney there is a group of peaks known as Milestone Mountain, the highest of which is given as 13,682 feet. I find, however, that the line of sight to Mt. Whitney passes just south of the Milestone peaks.

As further tending to identify Mt. Whitney, there is a sharp, isolated peak just to the north, in the proper direction for a peak on the map named Mt. Russell, whose altitude is 14,190 feet.

The close agreement of the directions, together with the appearance and facts above noted, convince me that it is Mt. Whitney which we see. C. D. PERRINE.

MT. HAMILTON, CAL., January 18, 1909.

NOTE ON THE SPECTRUM OF COMET *c* 1908 (MOREHOUSE).

In *Lick Observatory Bulletins* Nos. 145 and 147 the writers have published the results of the spectroscopic observations, both visual and photographic, of Comet *c* 1908. In the early visual observations Mr. CAMPBELL noticed that the spectrum had unusual features. The carbon bands at λ 4737, λ 5165, and λ 5635 were present in their usual relative intensities, but three bands to the violet of λ 4737, and a feeble one near $H\beta$ seemed to be new, or at least in very much greater relative strength than in previous comets observed at Mt. Hamilton. Four spectrograms of the comet were secured. The new lines (or bands) were recorded strongly, with the exception of the one near $H\beta$, for which region the plates used are not very sensitive.

The continuous spectrum seems to be almost entirely absent —all but a few per cent. of the photographic light being concentrated in seven lines at λ 3913, λ 4003, λ 4023, λ 4255, λ 4276, λ 4549, and λ 4571, in two lines at λ 4690 and λ 4715 which are probably the edges of flutings in the fourth carbon band, and in two lines at λ 3869 and λ 3883 which are due to cyanogen. We are unable to suggest a probable origin for the first seven lines mentioned. The six lines between λ 4003 and λ 4571, both inclusive, are no doubt identical with three pairs of lines observed by CHRÉTIEN[1] in the spectrum of

[1] *Comptes Rendus*, **145**, 549, 1907.

Comet *d* 1907, and three bands observed by DESLANDRES[1] and EVERSHED,[2] all using objective-prism spectrographs. Radiations having these wave-lengths seem to be relatively strong in the tails of comets, as it is difficult otherwise to account for their essential absence from the spectra of the heads of Comet *d* 1907 and other comets, as observed with slit-spectrographs.

The most striking feature of the spectrograms is the nearly complete concentration of the light in pairs of lines (or bands) with intervals between the pairs approximately proportional to the wave-lengths of the lines;—that is, $\frac{\Delta\lambda}{\lambda}$ is constant, within the unavoidable errors of observation. The existence of these pairs of lines, with the lines in the pairs separated by about the same intervals, is strongly suggestive of closely related origins. The most promising hypothesis as to their origin seems to us to be that they are related to each other in much the same way as the well-known carbon bands or cyanogen bands are related. We are inclined toward the opinion that the six lines referred to may be the edges of flutings in three bands of some element or compound not yet observed in the laboratory.

In an important paper on the comet spectrum, M. DESLANDRES[3] expresses the opinion that the doubling of the lines is "probably a Doppler effect." As the relation, $\frac{\Delta\lambda}{\lambda} = \text{constant}$, always holds for displacements of the lines throughout a spectrum by virtue of the motion of the light source in the line of sight,—the Doppler-Fizeau effect,—we had considered this explanation, but discarded it as improbable. It may be of value to state briefly the reasons which led us to look for a different explanation.

The pairs of bright lines or bands forming the basis of this discussion are: λ 4003-23, λ 4255-76, and λ 4549-71. Possibly the lines at λ 4690 and λ 4715 may also be included, but we feel confident that they are parts of the blue carbon band usually observed in comet spectra. The interval between the pairs, as observed by DESLANDRES on October 14th and November 1st, and by us on November 28th, remained constant within

[1] *Comptes Rendus*, **145**, 445, 1907.
[2] *Monthly Notices R. A. S.*, **68**, 16, 1907.
[3] *Comptes Rendus*, **147**, 951, 1908.

the errors of observation, and amounted to about twenty-one tenth-meters in the $H\gamma$ region. As a Doppler-Fizeau effect, this corresponds to a relative motion of 1450^{km} per second in the line of sight.

Assuming the inner section of the tail to lie, as usual, in the prolongation of the radius vector, the observed speed of 1450^{km} would be the projected equivalent of speeds of 2040, 2240, and 1840^{km} per second along the tail, or of 2040, 1920, and 2380^{km} per second transverse to the tail, respectively, on the three dates quoted.

The spectrograms show that by far the greater part of the photographic light of the comet's head and inner tail,—and perhaps of the entire tail,—falls in the six lines in question; which major part is divided about equally between the more refrangible and the less refrangible components.

The integrated image recorded by the ordinary camera should give results as to velocity not out of harmony with those indicated by the six lines into which the tail is chiefly resolved by the prism. These integrated images show by means of condensations within the tail that the speeds along the tail are of moderate and ordinary dimensions, not exceeding 30 or 40^{km} per second within say a million kilometers of the nucleus. Judging by the great brilliancy of many of the condensations, by the sharp bends, in which all the radiating material seems to fall, and by the fact that nearly all the brilliant part of the tail possesses a common general curvature, it does not seem that there can be much light radiated by matter moving fifty or sixty times as rapidly. Small and very narrow streamers are sometimes developed to considerable lengths between two successive dates, indicating probable speeds up to 200^{km} per second, but these emit only a small percentage of the total light of the tail, and therefore cannot have exerted an appreciable influence upon the observed spectrum.

The theory of a relative motion transverse to the axis of the tail, equal to $1900\text{-}2400^{km}$ per second, seems to meet with difficulties equally great. We should not expect rays of any known kind representing one component, or both components, of the three pairs of lines,—i. e., three eighths and perhaps three quarters of all the photographic radiations,—to move transversely to the tail, either along straight lines into distant space,

or by rotation, without the ordinary integrated images showing the effects. The photographs of the present comet suggest rotational effects,[1] but on too small a scale.

If a transverse motion were radial with reference to the nucleus and to the axis of the tail it would seem that a slit of the width employed should have a broad band for its image instead of two widely separated lines or bands, at least in the vicinity of the nucleus. If the motion were rotational, either a wide or a narrow slit should give a single line or band,—unless the tail were hollow and the slit took in both of its brightened borders. The integrated images show no such bright-bordered tails.

We judge that the prismatic-objective spectrograms obtained by PLUVINEL and by DESLANDRES show the two component images of a pair to be similar and parallel, at least out to a considerable distance in the tail. It seems improbable that any conditions, electrical or otherwise, would favor uniform speeds,—either radial or rotational,—throughout a long section of the tail.

Perhaps the strongest evidence against the Doppler-Fizeau explanation of the pairs lies in the apparent constancy of the intervals. These were observed to be the same on the three days, October 14th, November 1st, and November 28th; whereas, from the changed angle at the comet between its radius vector and our line of sight, we should have expected the intervals in the pairs to vary four or five tenth-meters from November 1st to November 28th, whether the assumed cause of the doubling be motion along or transverse to the tail. Such a variation did not occur. It should be noted that CHRÉTIEN'S observations of Comet *b* 1907, August 16th-18th, gave an average interval of twenty-two tenth-meters for the three pairs of lines, with the angle at the comet equal to 77°. The corresponding speeds would be 1550^{km} per second along the tail and 6900^{km} transverse to the tail. The intervals obtained by CHRÉTIEN for the three pairs of lines were respectively eight, seventeen, and thirty-nine tenth-meters. Whether the wide range in the values is real or accidental, due to the faintness of the lines in that comet, we cannot judge.

[1] Especially noteworthy in this connection are the observations by BALDET and QUENISSET, in *Comptes Rendus*, **147**, 1033, 1908.

The possible existence of an $H\beta$ radiation, as reported by Mr. CAMPBELL for October 20th, may prove of interest in connection with the suggested canal-ray Doppler-Fizeau effect.

As stated in our former paper on the spectrum, we incline to the view that the lines are observed nearly in their normal positions, and that the double lines are possibly the edges of flutings in bands not yet observed and identified in the laboratory. In this connection we should not overlook the faint lines at λ 453- and λ 423-, which may be the edges of other and fainter flutings in the same bands. Attention should be called to the strong line at λ 3913, which is not doubled. It seems to stand alone in this regard.

If we take either the more refrangible or the less refrangible component of each of the four pairs of lines between λ 4002 and λ 4715 and form the successive differences in the wave-lengths, we find that the second differences are constant within the errors of observation. This may indicate, as the source of these radiations, a substance or compound closely related to carbon.

Inasmuch as an identity has been shown to exist between certain comets and meteor streams, and laboratory analyses have shown meteorites to differ widely in chemical composition, it would not seem surprising that there should be different types of comet spectra.

It is hoped that PLUVINEL and DESLANDRES have been able to obtain observations additional to those already published which shall test thoroughly the various explanations suggested. Dr. CURTIS, in charge of the D. O. Mills Observatory at Santiago, Chile, has been asked to secure an extensive series of spectrograms with a one-prism slit spectrograph and with an improvised objective-prism spectrograph during the several months that the comet will be favorably situated for observers in the southern hemisphere.

W. W. CAMPBELL,
January, 1909. SEBASTIAN ALBRECHT.

THE BRIGHTNESS OF THE CORONA OF JANUARY 3, 1908.

The attempt by the writer to determine the total brightness (photographic) of the corona of August 30, 1905, was not successful, owing to the thin clouds. Two negatives, together

with some exposures on the preceding full Moon, were secured. These have little value, however, except to confirm the conclusion, reached from the 1908 eclipse, that most of the light of the corona emanates from within one minute of the Sun.

The attempt was repeated at the eclipse of January 3, 1908, when entirely successful observations were obtained. The details of these observations and a discussion of them will be published as a *Lick Observatory Bulletin*. Only the results will be given here.

The effect of the coronal light was obtained by allowing it to shine through an aperture on a sensitive plate, without the intervention of any optical parts whatever. On these same plates were impressed standard intensity squares for comparison.

From these negatives were obtained:—

1. The total actinic brightness of the corona.
2. The actinic brightness of the sky surrounding the Sun.
3. The limits from within which practically all of the effective light of the corona emanates.

It was found that nearly all of the effective light of the corona came from a ring around the Sun not over 1′ wide. Outside that limited region the light of the corona, although visible to the eye conspicuously, was not strong enough in comparison to be distinguishable.

The light from the above narrow region was found to equal 6.0 lamp units. The light from the full Moon, at its mean distance, was found to be 55.6 lamp units. The region of the corona observed gave, therefore, 0.108 as much light as the full Moon. This amount should be increased by the fainter parts of the corona, the brightness of which has not yet been determined.

The average intrinsic brightness of the narrow region of the corona observed was found to be 2.07 lamp units; that of the Moon, 2.65 lamp units. As the brightest parts of the narrow coronal ring are easily two, or possibly three, times the *average* brightness, the brightest parts of the corona are, therefore, brighter intrinsically than the full Moon.

This result accords with the naked-eye view of the corona, which shows a very brilliant and very narrow ring of light immediately surrounding the dark body of the Moon.

The light of the sky around the bright corona, from an area of 40,900 square minutes, was found to equal 3.0 lamp units. This gives an *average* intrinsic actinic brilliancy of .0026 as compared with the lamp, or of .001 as compared with the surface of the full Moon.

The intrinsic brilliancy of the region of corona observed is found to be eight hundred times that of the surrounding sky.

C. D. PERRINE.

MT. HAMILTON, CAL., January 27, 1909.

RESULTS OF FURTHER STUDIES ON THE STRUCTURE OF PHOTOGRAPHIC FILMS.

In a previous paper I gave the conclusion that the principal cause of the large discordances in measures of star photographs was to be found in the size and irregular arrangement of the silver grains composing the star image. Further investigations were undertaken to eliminate some of the trouble from these sources.

The details of the recent investigations will appear in a *Lick Observatory Bulletin,* and only the general results will be given here.

It was found that the accuracy was materially increased by giving sufficient exposure to insure light action entirely through the film, and full but slow development to give greater uniformity to the grain.

Rapid plates with an increased proportion of silver yield more accordant measures than plates with the normal amount of silver.

Where the structure is sufficiently uniform, as in Seed 23, and Transparency plates, it was found possible, by observing the above requirements, to produce negatives such that the range among the measures is only twice the uncertainty of the measures themselves.

Thin films appear to give much more reliable results than thick ones.

C. D. PERRINE.

MT. HAMILTON, CAL., January 22, 1909.

Note Concerning Volume VIII, "Publications of the Lick Observatory."

The volume referred to in the title, now issuing from the bindery of the State Printing Office, Sacramento, contains heliogravure reproductions of the late Director Keeler's photographs of nebulæ and star clusters made with the Crossley reflector. Other contents are a description of the Crossley reflecting telescope by Director Keeler, a list of the nebulæ and clusters photographed, a catalogue of 744 new nebulæ discovered on the negatives, and new determinations of the positions of the nebulæ previously known in the regions of the sky covered. It is hoped that the regular correspondents of the Lick Observatory can be supplied promptly with copies. The cost of the volume has been unusually high on account of the expensive processes and materials employed. There are seventy-one full-page heliogravure reproductions, printed by hand-press on suitable paper. The price of the volume has been fixed at $5.00, postage paid. Subscriptions may be sent to the University Press, Berkeley, California.

W. W. Campbell.

Mt. Hamilton, Cal., January 4, 1909.

GENERAL NOTES.

Astronomical Papers.—At the meeting of the Astronomical and Astrophysical Society of America, held at Put-in-Bay, Ohio, August 25-28, 1908, a programme consisting of thirty-one papers was presented. Titles of these papers, and abstracts from most of them, were printed in *Science* for December 11th. Titles and abstracts of twelve papers upon astronomical subjects presented before Section A of the American Association for the Advancement of Science, at the Baltimore meeting during convocation week, were printed in *Science* for January 22, 1909.

Notes from "Science."—The Paris Academy of Sciences has divided the La Lande prize between Professor W. L. ELKIN, director of the Yale Observatory, and Dr. F. L. CHASE, assistant astronomer in the observatory, for their papers on "The Parallax of 163 Stars." Mr. M. F. SMITH, assistant in the observatory, was given honorable mention in the award.

Professor GEORGE DAVIDSON, head of the geographical department of the University of California, has been presented with the Charles P. Daly medal of the American Geographical Society.

The Vienna Academy of Sciences has elected M. HENRI POINCARÈ, the eminent mathematician, to honorary membership. Among the corresponding members elected is Dr. G. H. DARWIN, Plumian professor of astronomy at Cambridge.

Dr. H. MORIZE has been appointed director of the Rio de Janeiro Observatory in the room of the late Professor L. CRULS.

M. CHARLES E. STUIVAERT, associate astronomer in the Royal Observatory of Belgium, died on November 18th, at the age of fifty-seven years.

The Royal Society has given to Cambridge University the stellar spectroscopic equipment which has been in the care of Sir WILLIAM HUGGINS since 1871. It consists of the following instruments: A refracting telescope with an object-glass fifteen inches in diameter and fifteen feet in focal length, to

which is attached a spectroscope arranged for both visual and photographic work; and a Cassegrain reflecting telescope with a mirror made of speculum metal, eighteen inches in diameter and about seven feet in focal length, to which a spectroscope is attached with optical parts made of Iceland spar and quartz, for photographing the ultra-violet spectrum of stars. These two telescopes are mounted equatorially on a single polar axis, in such a way that they can be moved independently in declination. They are at present installed in a dome about twenty feet in diameter, in Sir WILLIAM HUGGINS's garden at Tulse-hill. The telescopes and the equatorial mounting were made by Sir HOWARD GRUBB, in Dublin, and the spectroscopes by Messrs. TROUGHTON and SIMMS. The instruments are described as being in excellent working order, and would only require such insignificant changes as are usually needed in passing from one series of observations to another in the ordinary work of an observatory, but a suitable dome will have to be provided for the proper installation of the telescopes.

Lord ROSSE bequeathed £1,000 to Trinity College, Dublin, for the science schools. His telescope and scientific instruments are left to his oldest son, with £2,000 for their upkeep.

George W. Hough.[1]—By the death of Professor GEORGE W. HOUGH, on New Year's day of the present year, astronomy and meteorology lost a follower who has made contributions of permanent value to both sciences. Those who enjoyed the privilege of acquaintance with Professor HOUGH will agree that he well deserved the tribute paid to him by a distinguished astronomer, who, in a personal letter, says: "He was a rare man among astronomers in giving to astronomical work good sound common sense. He never found a mare's nest, and never went into idle speculations where the maximum conclusions are deduced from the minimum facts. For more than thirty years I have admired his honesty and good faith in all scientific work. So far as I know, there is nothing he ever had occasion to correct or retract, which is saying a good deal in these days."

[1] This brief account of Professor HOUGH's life is taken in large part from a sketch to appear in the *Monthly Weather Review*, which was sent to me in advance of publication.—R. G. AITKEN.

George Washington Hough was born in Montgomery County, New York, on the 24th of October, 1836; graduated B. A. from Union College in 1856; married in 1870; and died at his home in Evanston, Ill., on the first day of the current year.

Upon leaving college, Professor Hough taught for a year or so in the schools of Dubuque, Iowa; and pursued graduate work in Harvard College; so that his serious astronomical work did not begin until 1859, when he accepted appointment as assistant astronomer in the Cincinnati Observatory, then justly celebrated on account of its powerful glass and its able director, General O. M. Mitchell. At the end of his first year in Cincinnati came promotion to the directorship of the Dudley Observatory, where he succeeded the late Dr. B. A. Gould.

His fourteen years of residence in Albany (1860-1874) constitute a period during which his inventive genius was at its best. It was here that his printing barometer was brought out in 1865. This instrument gives two graphical records of the barometric height, on different scales, and prints with a type-wheel the reading of the barometer, at the end of each hour, to the nearest thousandth of an inch. It was about this time, also, that his self-recording thermometer and anemograph were devised. In the *Annals of the Dudley Observatory*, Vol. II (Albany, 1871), may be found a description of these instruments, together with a continuous hourly record from the printing barograph for a period of five years. In 1871 he perfected his now well-known printing chronograph.

Examination of the reports of the Dudley Observatory during these years shows that Professor Hough, in addition to his interest in meteorology, gave full attention to the astronomical work of the observatory, carrying on meridian-circle observations of almanac stars, of planets and of asteroids, and also zone observations, and observations with the equatorial telescope. It is of interest to note that as early as 1867 he began to turn his attention to double stars, stating in his report for that year his intention of remeasuring the closer pairs from Struve's catalogue as opportunity offered.

An interval of five years, between 1874 and 1879, was devoted to commercial pursuits. The latter of these dates marks

his appointment to the directorship of the Dearborn Observatory, a post which he was destined to honor for the succeeding thirty years. The year 1879 also marks the beginning of a micrometric study of the surface of the planet *Jupiter,* which within a few years made him a leading authority upon this subject. Except for the year 1888, when the Observatory was moved from Chicago to Evanston, his study of *Jupiter* was uninterrupted to the end of his life, and his papers giving the results of this work are commended to students of planetary markings.

Professor HOUGH'S interest in double stars became more active when he secured the use of the fine 18½-inch Dearborn telescope, which already had an honorable record in work of this character. Beginning with the year 1881, he gave a portion of his time to the discovery of new double stars as well as to the measuring of pairs already known. So successful was he in this work that 648 new pairs stand to his credit. As many of these are exceedingly close and difficult, and a very large percentage of them sure to prove binary systems, they well merit the attention of astronomers. Quite recently Professor ERIC DOOLITTLE, of the Flower Observatory, has remeasured all the Hough stars, and published his results, together with the earlier ones by HOUGH and other observers, in a general catalogue,—a well-deserved compliment to the value of HOUGH'S work. It may be added that one of his discoveries, Ho 212 = 13 *Ceti,* has been shown to revolve in a period of seven and one half years—a period shorter than that of any other known visual binary except δ *Equulei.*

On the removal of the Dearborn Observatory to Evanston in 1888, a new dome was to be designed. That fine mechanical sense which had already enabled him to do much for the instrumental side of his science now led him to invent a roller-bearing dome and a most excellent observing chair, which have been copied in many important observatories.

Class-room teaching Professor HOUGH never considered his chief function. Yet no student ever left his lecture with the recollection of an unkind word or of an explanation that was not clear.

Sham and ostentation were foreign to his nature. In simplicity of life, accuracy of scholarship, singleness of purpose,

and kindliness of heart, his friends will all remember him as a worthy example.

The Total Solar Eclipse of May 8, 1910.—The following data were published by A. M. W. DOWNING, in *Monthly Notices of the Royal Astronomical Society*, No. 9, 68, 664, 1908:—

This eclipse is observable in Tasmania, though not under very favorable conditions, owing to the Sun's low altitude at the time of totality.

The particulars for Hobart are given on page 444 of the *Nautical Almanac* for 1910. It will be noticed that the Sun sets before the ending of the partial phase of the eclipse.

Port Davey, in the southwest of Tasmania, is, however, a more favorable station from which to observe the total phase of this eclipse, the duration of totality there being half a minute longer than the duration at Hobart. Some particulars of the eclipse as seen from Port Davey are given, as an example of eclipse calculations, on page 590 of the *Nautical Almanac* for 1910. For the convenience of observers these are reproduced here, and some additional particulars added.

PORT DAVEY. LONG. 146° 0′ E. LAT. 43° 22′ S.
Standard Mean Time (10^h East).

		d	h	m	s	Angle from North Point.	Angle from Vertex.
First contact	May	9	3	4	2	247°	99°
Total eclipse		9	4	11	55	52	272
		9	4	15	25	267	127
Sun sets		9	5	8			

With the existing errors of the lunar tables, the predicted times for the phases of the eclipse given above will be several seconds too late. It may be useful, therefore, to add the intervals in time from the instant when the cusps subtend a given angle at the Sun's center to the commencement of totality.

Angle of Cusps.	Time before commencement of totality.
90°	42^s
60	16
45	9
30	4
15	1

The Sun's altitude at the time of totality is 8°.

Note on the Life and Services of JOHN TEBBUTT.—An Australian correspondent has sent me a copy of the *Sydney Morning Herald* for October 17, 1908, containing an appre-

ciative review of the life and astronomical work of Mr. JOHN TEBBUTT, of Windsor, New South Wales. As explained in the review, which is published below, Mr. TEBBUTT is a private astronomer. His services have been continuous and exceedingly fruitful for several decades. In this connection it should not be forgotten that contributions from the southern hemisphere, where observers are scarce, have a value much greater than similar ones from the northern hemisphere, where active observatories exist in abundance. This is especially true of comet observations. For long stretches of time Mr. TEBBUTT was really the only active and accurate observer of these objects in the southern hemisphere. His energy and enthusiasm are worthy of wide recognition from astronomers in all countries, and the writer expresses the hope that Mr. TEBBUTT's activity has not ceased. W. W. C.

Mr. JOHN TEBBUTT has just issued a most interesting popular account of his astronomical work at Windsor from 1853 to the end of 1907. This is a remarkable instance of a lifelong devotion to science, and though Mr. TEBBUTT has his reward in the knowledge of much fine work accomplished, and incidentally in his high reputation as an astronomer, too few of us realize the importance of the contributions to science New South Wales has thus been able to make. The sketch now issued may do something to remove an ignorance which is not altogether the fault of the man in the street, for astronomical papers are not as a rule published in a form accessible and intelligible to him. Mr. TEBBUTT's grandfather arrived in Sydney about the close of 1801, traveling, since there was no other way, in the convict ship "Nile," on which was the celebrated MARGARET CATCHPOLE. The family shortly after their arrival settled in the Hawkesbury district, and carried on a general business at Windsor from 1829 to 1843. It was here that JOHN TEBBUTT was born in 1834. After a time the local Church of England clergyman undertook his education, and brought him up on sound classical fare, but without neglecting mathematics and the "use of globes." Mean time, the family had acquired the estate known as the Peninsula, and a house had been erected in 1845. Mr. TEBBUTT was still a boy when he first felt the fascination of astronomy, and he tells us he made his first observation—that of a comet—in 1853, when he possessed only a marine telescope and a celestial atlas. The brother of Mr. STILES, the clergyman, had been a midshipman in the Royal Navy, and he suggested the purchase of a sextant and a book on navigation. There was in the house a Scotch eight-day clock, with seconds pendulum, which is still going. In the early days Mr. TEBBUTT regulated the clock by sextant observations, and also by transits of the Sun and stars over two fixed plumb-lines adjusted at a considerable distance from

each other and in the plane of the meridian. He had read that the Sun rotated in about twenty-five days, and proceeded to verify this in an ingenious manner. This led him to make his first astronomical publication—in the *Sydney Morning Herald* of 1854. In 1857 there was a total eclipse of the Sun. It happened that Windsor was almost at the center of the Moon's dark shadow. In 1858 comet Donati appeared, and with the rough instruments at his disposal Mr. TEBBUTT calculated its orbit. Another comet appeared in 1860, and Mr. TEBBUTT's orbit for this, calculated from sextant observation, was confirmed by our first Government Astronomer, Rev. W. SCOTT, who had a small equatorial at Sydney. The year 1861 was notable, for then for the first time a new comet was discovered in Australia. Mr. TEBBUTT detected it on May 11th, but it did not become visible in the northern hemisphere until near the end of June. At the time it was first noticed TEBBUTT's comet was about 124,000,000 miles away, and as it showed no tail (moving in the line of sight) it was a difficult object. Subsequently it showed a tail, stretching a third of the way round the heavens, and it was one of the most brilliant comets Sir JOHN HERSCHEL had ever seen. Full justice was done, we are glad to know, to Mr. TEBBUTT's claims for priority in discovery. This comet has a period of some 409.4 years, so that it will not come back until about 2271. At this time Mr. TEBBUTT obtained an excellent refracting telescope. At the close of 1863 he erected a small observatory with his own hands—down to the bricklaying and slating. A two-inch transit instrument was added to the equipment. A small octagonal tower was built for the telescope. Meteorological observations had already begun. Mr. TEBBUTT decided to devote himself to occultations of stars by the Moon, to eclipses of *Jupiter's* satellites, and positions of comets. There were, of course, no cable messages in those days, and his work was therefore quite isolated. In 1867 a memorable flood occurred and the observatory was almost completely submerged though the instruments had been removed in time—the only flood which has entered the buildings up to the present time. In 1869 Windsor was placed in the list of observatories in the *British Nautical Almanac*—a well-deserved recognition. A larger telescope was added in 1872, and next year Mr. TEBBUTT was elected F. R. A. S. A great event was the observation of the transit of *Venus* in 1874—at a temperature of 109°.5 in the shade. A more substantial observatory was built in 1879, and a Grubb eight-inch equatorial added in 1886. An impetus was given to local astronomical work in 1895 by the establishment of a New South Wales branch of the British Astronomical Association, and of this Mr. TEBBUTT was first president. Mean time Mr. TEBBUTT's systematic work had been carried on through all these years with the utmost devotion, and to the great advantage of science; his material in fact early earned a reputation for remarkable accuracy, and was relied on by the most eminent of European calculators. This work drew to a close in 1904, when Mr. TEBBUTT had attained his seventieth year. It had included some 1,400 occultations of stars by the Moon, many valuable measurements of double stars, 120 papers in the

Monthly Notices, many other contributions to astronomical journals, and much work on cometary orbits—Mr. TEBBUTT has discovered several comets besides the notable one of 1861 referred to. Such single-souled labor is not easy to parallel, and it must be remembered that most of it was carried out without any assistance from others, and without that sympathy and intercourse which does so much to lighten the toil of scientific investigation.—W. G. P.

NEW PUBLICATIONS.

Annals of the Astronomical Observatory of Harvard College.

Vol. LIV, A catalogue of 36,682 stars fainter than the magnitude 6.50 observed with the 4-inch meridian photometer, forming a supplement to the revised Harvard photometry. EDWARD C. PICKERING. Cambridge. 1908. 4to. 280 pp.

Vol. LVII, Part II, Comparison stars for 252 variables of long period. LEON CAMPBELL. 1908. 73 pp.

Vol. LIX, No. 2, Photographic photometry on a uniform scale. EDWARD S. KING. 29 pp., with one plate.

Vol. LX, No. 9, A catalogue of photographic charts of the sky. 20 pp.

Vol. LXIV, No. 1, Observations with the meridian photometer during the years 1902 to 1906. 32 pp.

Vol. LXIV, No. 2, The variable star SS *Cygni,* 213843. LEON CAMPBELL. 20 pp., with one plate.

Vol. LXIV, No. 3, SHÖNFELD'S comparison stars for variables. 34 pp.

Annuaire pour l'an 1909, publié par le Bureau des Longitudes. Paris. 16mo. vi + 710 + A 116 + B 57 + C 11 + D 47 pp. Paper. Price, 1 fr. 50 c.

Anuario del observatorio astronómico nacional de Tacubaya para el año de 1909. México. 1908. 16mo. 610 pp. Paper.

Annuario astronomico pel 1909 Publicato dal R. Osservatorio di Torino. Torino. 1909. 8vo. 93 pp. Paper.

Astronomiska Iakttagelser och Undersökningar å Stockholm's Observatorium. Band 9. Uppsala and Stockholm. 1908. 4to. Paper. N : r. 1, Analytische Merkmale des Dreikörper-Problems von KARL BOHLIN. 72 pp. N : r. 2, Integral-Entwickelungen des Dreikörper-Problems von KARL BOHLIN. 141 pp., mit 11 Tafeln und 3 Textfiguren.

JACOBY, HAROLD. Rutherfurd photographs of stars surrounding 59 *Cygni*. Contributions from the Observatory of Columbia University, No. 25. New York. 1908. 8vo. 23 pp. Paper.

Katalog der astronomischen Gesellschaft. Zone — 14° bis — 18°. Catalogue of 8,824 stars between 13° 50′ and 18° 10′ of south declination, 1855 for the equinox 1900 from observations with the Pistor and Martins transit circle at the United States Naval Observatory, Washington, D. C., during the years 1894 to 1905, by A. N. SKINNER. Leipzig. 1908. Folio. 23 + 180 pp. Paper.

KLINKENBERG, L. M. Die Greenwich-Deklinationsbestimmungen von Polaris, 1851-1905. Proefschrift. Rotterdam. 1908. 4to. 84 pp. Paper.

POOR, CHARLES LANE. An investigation of the figure of the Sun and of possible variations in its size and shape. Contributions from the Observatory of Columbia University, New York, No. 26. Reprinted from the Annals of the York Academy of Sciences, Vol. XVIII. August, 1908. 8vo. 385-424 pp. Paper.

Publications of the Astronomical Laboratory at Groningen. Groningen. 1908. Folio. Paper. No. 19, The proper motions of 3,300 stars of different galactic latitudes, derived from photographic plates prepared by Professor ANDERS DONNER, measured and discussed by Professor J. C. KAPTEYN and Dr. W. DE SITTER. xiii + 42 + T 115 pp. No. 21, A determination of the apex of the solar motion according to the method of BRAVAIS, by H. A. WEERSMA. 74 + xxxi pp.

Publications of the Lick Observatory. Vol. VIII, Photographs of nebulæ and clusters, made with the Crossley reflector by JAMES EDWARD KEELER. Sacramento. 1908. 8vo. 46 pp., with 70 plates. Cloth. Price, $5.00.

Publications of the Washburn Observatory of the University of Wisconsin. Vol. XII. Madison. 1908. 4to. 317 pp. Paper. Part I, Proper motions of faint stars, by GEORGE C. COMSTOCK. Part II, Meridian observations of comparison stars, by ALBERT S. FLINT.

Recherches astronomiques de l'observatoire d'Utrecht III, The variable star U *Geminorum*, by J. VAN DER BILT. Utrecht. 1908. 8vo. 115 pp., with 29 plates. Paper.

SCHŒNBERG, E. Die Polhöhe der Jurjewer (Dorpater) Sternwarte aus Talkott-Beobachtungen mit dem Repsoldschen Zenitteleskop. Publikationen der Kaiserlichen Universitäts-Sternwarte zu Jurjew (Dorpat). Band XXI, Heft 1. Dorpat. 1908. Folio. 33 pp., with one plate. Paper.

TEBBUTT, JOHN. Astronomical Memoirs. Sydney. 1908. 8vo. 132 pp., with 5 illustrations.

Veröffentlichungen des königlichen astronomischen Rechen-Instituts zu Berlin. No. 36, Genäherte Oppositions-Ephemeriden von 29 kleinen Planeten für 1909 Januar bis 1909 Juli. Unter Mitwirkung mehrerer Astronomen, insbesondere der Herren A. BERBERICH und P. V. NEUGEBAUER, herausgegeben von J. BAUSCHINGER. Berlin. 1909. 8vo. 12 pp. Paper.

WOLFER, A. Die Häufigkeit und heliographische Verteilung der Sonnenflecken in Jahre 1907; Vergleichung mit den Variationen der magnetischen Deklination. Die partiale Sonnenfinsternis vom 28 Juni, 1908, beobachtet in Zürich. Forstsetzung der Sonnenfleckenliteratur. Astronomishe Mitteilungen gegründet von Dr. RUDOLF WOLF. Nr. XCIX. Zürich. 1908. 8vo. 32 pp. Paper.

Minutes of the Meeting of the Board of Directors of the Astronomical Society of the Pacific, held at Chabot Observatory, Oakland, Cal., Saturday, January 30, 1909.

President Burckhalter presided. The minutes of the meeting held November 28, 1908, were approved.

The Committee on Location was authorized to procure a place for holding the annual meeting, March 27, 1909.

The following was elected to membership:—

The Chief Astronomer, Department of Interior, Ottawa, Canada.

President Burckhalter announced the appointment of the following committees:—

Auditing Committee: F. R. Ziel (Chairman), J. A. Langstroth, W. H. Lowden.

Nominating Committee: José Costa (Chairman), Otto Von Geldern, J. H. Moore, W. H. Smyth, B. L. Hodghead.

Adjourned.

Minutes of the Meeting of the Society, held in Chabot Observatory, Oakland, Cal., January 30, 1909, at 8 o'clock p.m.

President Burckhalter presided. The minutes of the November, 1908, meeting were approved.

There being no further business, the President introduced Professor Alexander G. McAdie, official in charge of the U. S. Weather Bureau in San Francisco, Cal., who delivered an interesting lecture on "Mountain Sites for Observatories." The lecture was illustrated by lantern slides.

The second lecture of the evening was to have been delivered by Professor T. J. J. See, Director of the Naval Observatory, Mare Island, Cal. Professor See was unfortunately unable to be present because of an attack of appendicitis. His lecture was read by the Secretary. It was entitled, "The Laws of Cosmical Evolution and the Expansion of the Solar System beyond *Neptune.*" The lecture was illustrated by lantern slides. Professor See's paper announced for the first time his new theory of cosmical evolution in which was given his argument for the existence of one or more trans-Neptunian planets.

Adjourned.

OFFICERS OF THE SOCIETY.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XXI. San Francisco, California, April 10, 1909. No. 125

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO DR. GEORGE WILLIAM HILL.

By Charles Burckhalter.

The eighth award of the Bruce Gold Medal of this Society has been made to Dr. George William Hill.

To those having understanding of the statutes, and the method governing the bestowal of the medal, it goes without saying that it is always worthily bestowed. The statutes require that, for each medal awarded, eminent astronomers,—the directors of six of the greatest observatories in the world,—shall be asked each to nominate three astronomers worthy to receive the Bruce Medal "for distinguished services to astronomy." The six observatories have always been Harvard, Lick, and Yerkes in this country, and Berlin, Greenwich and Paris in the Old World. From the nominations thus made the Directors of this Society, by ballot, choose the Medalist.

The list of names of those whom we have thus honored, and in honoring them we have honored the Society, is an inspiring one—all household names in astronomy. The first award was to Simon Newcomb, a native of Nova Scotia; the second to Arthur Auwers, a German; the third to Sir David Gill, an Englishman; the fourth to Giovanni Virginio Schiaparelli, an Italian; the fifth to Sir William Huggins, an Englishman; the sixth to another German, Hermann Carl Vogel; the seventh to Edward C. Pickering, the first native-born American to receive the medal; and the eighth to our present medalist, also an American. The Bruce Medal, like astronomy, knows nothing of boundaries.

In a paper in the *Popular Science Monthly* for October, 1908, Professor PICKERING calls attention to the fact that there are only six Americans who are members of three or more of the seven leading National Scientific Societies (England, France, United States, Russia, Germany, Austria and Italy) and of these six, three are astronomers; and I wish to add, of the three astronomers our medalist is one. Professor PICKERING also points out that every living Bruce Medalist belongs to three or more of these societies.

Although this is but the eighth award of the medal, so great is the care taken in its bestowal, and with such wisdom have the selections been made, that the Bruce Gold Medal is already recognized as one of the greatest honors that can be conferred upon an astronomer.

The statutes for the bestowal of the Bruce Medal require the President of the Society at this meeting to "Announce the award and the reasons for making it." Let me here say that no adequate review of Dr. HILL's work can be comprised in this address; in his "Collected Mathematical Works" there are eighty-four memoirs, every one of which shows the master mind. And I wish at once, frankly, to confess my inability to give an opinion of the value of Dr. HILL's services to astronomy, and in this, your President feels that he is but one of a large company. Only specialists in celestial mechanics are competent to appreciate and appraise the utility and importance of his monumental achievements; the opinions of those intellectual giants who are his colaborers, alone can reflect to us a true estimate of their value.

Professor NEWCOMB in his "Reminiscences of an Astronomer" says of Dr. HILL that "he will easily rank as the greatest master of mathematical astronomy during the last quarter of the nineteenth century." Wedded to his chosen field of labor, he worked, year after year, scarcely known to the public, patient, underpaid, his ability appreciated by only a few of his colleagues, but content that he could advance his beloved science. Speaking of this time, NEWCOMB says of him: "Here was perhaps the greatest living master in the highest and most difficult field of astronomy, winning world-wide recognition for his country in the science and receiving the salary of a department clerk."

The list of honors conferred upon our medalist by institutions of learning in this and foreign countries is a long one, among which I may mention the Damoiseau prize, of the Paris academy, the degree of Doctor of Laws, by Cambridge University, England, and the gold medal of the Royal Astronomical Society. Our own recognition is, of necessity, somewhat tardy, for he has been nominated again and again by eminent astronomers, for the honor of the Bruce Medal.

I have said that only an expert can rightfully weigh such work as that of our medalist. Such an one is Mr. HENRI POINCARÉ, who has written, in French, an introduction to the "Collected Mathematical Works of George William Hill." From this, the following abstract has been prepared by Dr. R. G. AITKEN, of the Lick Observatory:—

"Dr. HILL," says POINCARÉ, "is one of the most original figures in the American scientific world. Throughout all his works and his calculations he has remained a stranger to the feverish life that has troubled others; he has conducted his researches in isolation, formerly in the bureau of the Nautical Almanac, more recently at his quiet home in the Hudson Valley. This reserve, I was about to say this shyness, has been a happy circumstance for science, for it has permitted him to carry his ingenious and patient researches to their conclusion without suffering distractions from the constant accidents of the world outside."

Dr. HILL was born in New York, March 3, 1838. His father, an Englishman, came to America in 1820 at the age of eight; his mother, of an old Huguenot family, transmitted to him the traditions of the earliest colonists of America. He passed his infancy at the farm at West Nyack, about twenty-five miles from New York, which his father bought shortly after HILL's birth.

"He always loved his home, he returned to it as often as he could, and when he resigned from the Nautical Almanac Office he made his permanent home there, and there he pursues his studies in tranquility, avoiding, as far as possible, even journeys to New York."

At the age of seventeen he entered Rutger's college, New Brunswick, New Jersey, where his professor in mathematics

was Dr. STRONG, a friend of BOWDITCH, the translator of "Laplace's Mécanique Céleste."

"Dr. STRONG was a man of traditions, one who praised the bygone times; for him EULER was the god of mathematics, and after EULER, decadence began; it is true that this is a god one may worship with profit. With rare exceptions Dr. STRONG's library was pitilessly closed against all books of later date than 1840. Happily, excellent works on celestial mechanics were written prior to 1840, for example, those of LAPLACE, LAGRANGE, POISSON, and PONTÉCOULANT. These were the masters by whom HILL was introduced to the rudiments of the science."

Receiving his degree in 1859 he went to Harvard to continue his mathematical studies, but in the spring of 1861 joined the Nautical Almanac staff and spent the next thirty years of his life in that service. Those were the most fruitful years in point of scientific productions. At this time the Nautical Almanac Office was at Cambridge, Mass., under the direction of Professor RUNKLE, the founder of the *Mathematical Monthly,* in which prizes were proposed for the solution of mathematical problems. "One of the first articles published," says POINCARÉ, "revealed the hand of a master and easily gained the prize. It dealt with the functions of LAPLACE and the figure of the Earth. The author was Mr. HILL, who was just about to leave college."

HILL continued to make many contributions on various mathematical subjects, generally, however, connected in some way with celestial mechanics, to the *Mathematical Monthly,* and to the *Analyst* and similar journals.

While the Nautical Almanac Office remained in Cambridge under RUNKLE, HILL's work for it was done at his home in West Nyack. But, in 1877, when NEWCOMB assumed charge, "he wished to undertake a colossal task, the reconstruction of the tables of all the planets; Mr. HILL's part in this task was the most difficult; it was the theory of *Jupiter* and *Saturn,* with which he began to busy himself about 1872." He could not well carry on this work away from his chief and his colleagues, so was obliged to leave his home, a sacrifice readily made in view of the importance of the work. But he returned to his home when the bureau was moved to Washington.

In 1892 he resigned from the Nautical Almanac. For a short time thereafter he held a professorship in Columbia University, but he did not continue in this position long, and since then "has lived alone with his books and his souvenirs."

Inspection of the tables of contents in the four volumes of his "Collected Mathematical Works," published by the Carnegie Institution, of Washington, shows what a wide range his investigations took, in every department of celestial mechanics.

HILL's greatest work, according to all competent judges, consists in his researches on, and contributions to, the lunar theory. This account of it is based on POINCARÉ's introduction. He says it is the work to which HILL "devoted all the originality of his genius."

To comprehend HILL's work, POINCARÉ gives a brief account of the state of the theory when HILL began his work. Two great works on this subject had been completed at this time—HANSEN's and DELAUNAY's—each exhibiting the results of the highest sagacity and of extreme patience.

The methods adopted by these two investigators are radically different; HANSEN, who completed his work first, had in mind the purely utilitarian object of computing accurate lunar tables, hence he calculated numerical co-efficients directly and did not trouble himself to find analytical expressions. The tables in actual use to-day are based on HANSEN's calculations, and it is probable that the new theories, more scientific, more satisfactory in their spirit, will not give very different results. DELAUNAY, on the other hand, presented his inequalities in the form of algebraic formulas. "He gives us, then, not only the theory of the Moon, but the theory of any satellite that revolves, or that may revolve about any planet whatever. From this point of view he leaves HANSEN far in the rear. The method which has led him to this result constitutes the most important advance that has been made in celestial mechanics since LAPLACE. To-day, perfected and shortened, it has become an instrument that every one can use, and that has already rendered good service in every part of astronomy."

Unfortunately DELAUNAY's series converges only with excessive slowness and is therefore unsuited to numerical computations. HILL promptly mastered DELAUNAY's theory and made

it the subject of various memoirs, but his own method is very different and very original.

DELAUNAY'S series depends on five constants, the eccentricities, the inclination, the solar parallax, and a quantity called *m*, which depends upon the mean motions. If we suppose the first four to become zero, we have a particular solution of the differential equations. This solution will be very much more simple than the general one since the greater part of the inequalities will disappear, the only remaining one being the one known as the "variation."

On the other hand this solution does not precisely represent the Moon's trajectory, but it will serve as a first approximation, since the neglected constants are in effect very small. The choice of *this* first approximation is far more advantageous than the Keplerian ellipse, since for this ellipse the perigee is fixed, whereas in the real orbit it is in motion. The differential equations are at the same time simplified, since, the eccentricity and parallax being zero, the Sun is supposed to describe a circumference of very great radius. Mr. HILL again simplified the equations by judiciously choosing his variables. He does not express them in polar coördinates, but in the rectangular, and this is a great step in advance. Again his variables are not referred to fixed axes, but to axes possessing a uniform rotation, equal to the mean angular motion of the Sun. This was a new simplification, since the time no longer figures explicitly in the equations. "But the most important advantage is the following: For an observer situated on those moving axes the Moon will appear to describe a closed curve, if the eccentricities, the inclination and the parallax are zero. As the differential equations are otherwise rigorous, *this is the first example of a periodic solution of the problem of three bodies* whose existence has been rigorously demonstrated. Recently periodic solutions have assumed capital importance in celestial mechanics. [POINCARÉ himself is one of the foremost investigators in this branch, if indeed he has an equal.] But our medalist was not content merely to demonstrate its existence; he studied this orbit (or these orbits) in detail, and determined point by point the closed trajectories and calculated the coördinates of these points to many decimals."

Not to follow POINCARÉ's discussion in too much detail, it may suffice here to say that in the further transformations and solutions of these equations, Mr. HILL showed as much daring as originality. His solution involved the consideration of *an infinite number of linear equations.* Not only did he not hesitate to consider these, but he also studied determinants of an infinite order, a thing never before attempted[1] and, happily, his daring was justified by his success.

If we compare his methods with those of DELAUNAY, we shall find that HILL's method by three approximations gave results for the constant of the motion of the lunar perigee correct certainly to thirteen decimals, whereas (to quote from HILL's own paper) "Although DELAUNAY has been at the great pains of computing eight terms of this series, they do not suffice to give correctly the first four significant figures [eight decimals] of the quantity sought. . . . As well as can be judged from induction it would be necessary to prolong the series, in powers of m, as far as m^{27}, in order to obtain an equally precise result."

This will suffice to illustrate the great advance made by HILL in the development of the lunar theory, for the method thus applied to the motion of the lunar perigee may also be applied to the motion of the node. The main difficulties are thus conquered, and the subsequent approximations are relatively easy. Nevertheless practical difficulties still remain, and the field is open for new improvements and new theories. It is unnecessary in this connection to do more than merely to refer to the work of another eminent investigator, Professor E. W. BROWN, who has developed methods of which much is expected.

The inequalities in the lunar motion so far discussed have been those due to the action of the Sun. They are the ones that would be produced if only the Sun, the Moon, and the Earth existed, and they were reduced to material points. But there are other inequalities in the lunar motion, produced in part by the direct action upon the Moon of the other planets, and in

[1] At least not to Dr. HILL's knowledge at this time. It appears that ADAMS, of Neptunian fame, had been led by his researches to a determinant very nearly identical with the one discovered by HILL. POINCARÉ also refers to a memoir by M. KOTTERITZSCH in *Poggendorf's Annalen*, though he says the method there given had "nothing in common with that of the American Geometer."

part, indirectly, by the disturbing action of these planets upon the motion of the Earth about the Sun. Further, the Earth is not spherical, and its equatorial protuberance exercises an influence upon the lunar motion.

In the planetary perturbations of the Moon's motion we may further distinguish between the secular variations and the periodic. Mr. HILL has studied successively the secular acceleration of the mean motion, that of the motion of the perigee, and the influence of the variations of the ecliptic. Nor has he neglected the others, and he has also given careful study to the effect of the oblateness of the Earth and discussed the results of the pendulum determinations of the force of gravity on the Earth's surface.

But the lunar theory did not absorb all of HILL's time or energy. Time and again he turned to investigations dealing with general problems, the general theory of planetary perturbations and special problems in this field. His largest piece of work of this kind is the one undertaken for the Nautical Almanac in connection with and as part of NEWCOMB's "colossal task," referred to above, of the complete discussion of the mutual perturbations of *Jupiter* and *Saturn*.

LAPLACE had entered upon this theory which presents very great difficulties because of what is termed "the great inequality," but his evaluation of the terms of the second order was but a rough approximation. HANSEN was more fortunate, and so arranged his calculations that he was able to estimate the importance of terms he neglected, but he carried out his work completely only in the case of *Saturn*. For *Jupiter* he was content to stop with terms of the first order. We may pass over other memoirs as relatively unimportant until we come to that of LE VERRIER, published in 1876. His theory is indeed complete, but his formulæ are entirely literal, and so arranged that the co-efficients of the inequalities are expressed in terms of corrections to all of the osculating elliptic elements. In practice this leads to excessively long computations and there are apparently some outstanding errors in the formulæ; besides, the tables are not convenient to use. But HILL began his investigations in 1872, before LE VERRIER's results were published and at a time when it was uncertain when they would

be published. The tables then in actual use were BOUVARD'S, and these were quite inadequate to meet the needs of astronomers. Having a purely practical end in view, the construction of accurate tables in the shortest possible time, HILL did not seek to develop a new method of investigation. He adopted HANSEN'S, but with modifications that greatly simplified it. So great an amount of computing was involved in this research that Mr. HILL devoted to it seven and a half years of time, being relieved during this time of all routine duties in the Nautical Almanac Office and having the services of an assistant to check by duplicate computations all the more important calculations. The result of this long, and in many ways necessarily tedious work is a splendid volume of theoretical researches, and two volumes of accurate tables, one of the motion of *Jupiter,* the other of the motion of *Saturn.*

The recent progress of celestial mechanics has received and continues to receive Mr. HILL'S constant attention. HANSEN'S and DELAUNAY'S methods, GYLDÉN'S intermediate orbit, the recent developments in periodic solutions of the three-body problem [as presented by POINCARÉ, DARWIN and others], have all been assimilated, and many of them analyzed and discussed in some of his published memoirs.

In his concluding sentence POINCARÉ says: "There is therefore not a single part of celestial mechanics to which he is a stranger, but his chief work, that which will make his name immortal, is his theory of the Moon. It is there that he is not only an able artist, a careful investigator, but an *inventor,* original and profound. I do not wish to say that the methods which he created are applicable only to the Moon. I am well persuaded to the contrary; I think that those who are engaged in study of the minor planets will be astonished at the relief from difficulties they will experience on the day when, having fathomed their spirit, they apply them to this new object. But at present it is for the Moon that they have proved themselves. When they enter upon a wider domain, we ought not to forget that it is to Mr. HILL that we owe so precious an instrument."

We have earnestly hoped that our medalist would be with us this evening, but in a letter to Dr. HALE he said he did not feel strong enough to undertake the journey; therefore, in

his absence, I hand to you, Mr. Secretary, for transmission to Dr. HILL, this medal, the highest honor this Society can possibly confer upon an astronomer, and with it I ask you to send the greetings and best wishes of the Astronomical Society of the Pacific, and that we trust the evening of his life may be a long and happy one.

March 27, 1908.

THE LAWS OF COSMICAL EVOLUTION AND THE EXTENSION OF THE SOLAR SYSTEM BEYOND NEPTUNE.

By T. J. J. SEE.
(Abstract of address delivered January 30, 1909.)

It has long been considered somewhat of a reproach to astronomy that the processes of cosmogony have remained so obscure that definite laws could not be established regarding even the mode of formation of the solar system, while still less was known about the laws for the development of other systems in space. In view of the great progress of the physical sciences since the time of LAPLACE, one is compelled to admit that this criticism of the oldest and most exact of the physical sciences is not wholly unjust and without a certain foundation. Not only has the failure of researches in cosmogony affected astronomy adversely, but it has also narrowed the field of effort in several of the related sciences. This should not, however, occasion surprise among those who study the history of the physical sciences. For as cosmogony depends on the other sciences for its fundamental data, any circumstance which has affected them adversely would also retard the development of cosmogony itself, and *vice versa*.

In addition to the natural difficulties inherent in the development of a complex and dependent science like cosmogony, another has arisen from the demoralization of spirits due to the failures of previous investigators. Those who have labored for years without gaining any satisfactory light on the subject may easily convince themselves that there are no definite laws

of celestial development; or imagine that such laws as exist are the outgrowth of various processes,—under repulsive and even explosive forces, as well as under the more familiar attractive force of gravitation. The investigator who has repeatedly failed will readily persuade himself that nature has few, if any, simple laws. This mistaken tendency of many minds is supported and confirmed by the diversity of process apparently required to harmonize discordant phenomena; and the love of novelty thus suggested is often stronger than the love of truth.

Accordingly we have a multitude of theories, most of which have no foundation whatever, and should never have been advanced. The promulgation of theories wholly devoid of foundation is injurious to science and simply aids in the propagation of error. When nothing is known, however, almost any hypothesis which unites and harmonizes phenomena is philosophically justifiable, and may be of some value for the time being; but when means exist for confronting hypotheses with observations, so as to establish contradictions with known phenomena, it is idle and vain to consider any hypothesis which is not free from contradiction.

Heretofore most of the theories of cosmical evolution proposed have been involved in some inconsistency. Indeed, most of them have been directly contradicted by the most obvious phenomena, which admit of no dispute; and yet many of these baseless speculations have continued to circulate even in publications of supposed scientific standing. The vague theories put forth by persons of obscure mind only serve to muddy the stream, so that no one can penetrate beneath the surface; and this leads a considerable body of observers to concentrate attention chiefly on superficial phenomena, which have the double fascination of apparent obviousness and at the same time may be grasped without much labor. But sagacious investigators are not taken in by such palpable deceptions. They are accustomed to look beneath the surface, and realize fully that hard work, extending over many years, is the price which must be paid for discoveries of real value. Until results can be obtained which admit of no contradiction they prefer to wait for more light, and thus have been able to make

but few positive advances in cosmogony. In the present discussion we shall refer especially to the solar system, but the principles are obviously applicable to all systems in space, and we need not dwell on the universal character of the theory.

The roundness of the orbits of the planets and satellites has been remarked with wonder and admiration from the earliest ages of science. This remarkable geometrical property of the planetary paths excited the speculative curiosity of ARISTARCHUS and ARCHIMEDES, HIPPARCHUS and PTOLEMY, KEPLER and NEWTON; but while all geometers followed the Greeks in admiring nature's apparent preference for the circle, no one of them attempted to explain this tendency till LAPLACE promulgated the nebular hypothesis in 1796, and accounted for the circularity of the orbits by a rotation of the central mass under gradual acceleration, which would detach the attendant bodies quite gently and set them revolving in orbits approximately circular. LAPLACE'S explanation has been generally accepted, and for more than a century it has been universally assumed that the planets and satellites were originally detached from the central bodies which now govern their motions.

Yet as long ago as 1861 BABINET had proposed a mathematical criterion for testing the Laplacian theory, and on applying it to our system found that the classic nebular hypothesis was not confirmed. This criterion rests on the mechanical principle of the conservation of areas, according to which the moment of momentum of a rotating mass is unchanged whatever be the change in radius. Thus if ω be the angular velocity of rotation of a globe of radius r, ω' and r' the corresponding quantities at another epoch; then it follows that

$$r^2\omega = r'^2\omega'$$

On applying this formula to our actual system, with the numerical data adopted in *Astronomische Nachrichten* No. 3992, we find the results given in the accompanying table.

BABINET had applied his criterion to the case of the Earth and *Neptune* and found that the rotation of the hypothetical solar nebula when it was expanded to fill these orbits would not be rapid enough to detach these planets. As his criticism

of LAPLACE'S theory was destructive and not constructive, it shared the fate common to efforts of this kind, and has been generally lost sight of. Consequently the effect of BABINET'S test on current speculative thought was insignificant. The above table gives the best available data for all parts of the solar system, and shows that none of the planets and satellites were ever detached from the central masses which now govern their motions.

Thus we see that the premise underlying LAPLACE'S hypothesis, implying that the attendant bodies were detached by rotation, was false, and consequently the reasoning based thereon quite unjustifiable. Therefore his venerable explanation of the roundness of the planetary orbits falls to the ground, and another cause must be sought which admits of verification by means of criteria of acknowledged mathematical rigor.[1]

TABLE SHOWING THE APPLICATION OF BABINET'S CRITERION TO THE PLANETS AND SATELLITES, WHEN THE SUN AND PLANETS ARE EXPANDED TO FILL THE ORBITS OF THE BODIES REVOLVING ABOUT THEM.

Solar System.	Planet.	R_0 The Sun's Observed Time of Rev.	P_0 Observed Period of Planet.	R_c Time of the Sun's Rotation Calculated by BABINET'S Criterion.
	Mercury	25.3 days = 0.06267 yrs.	0.24085 years	479 years
	Venus		0.61237 "	1673 "
	The Earth		1.00000 "	3192 "
	Mars		1.88085 "	7424 "
	Ceres		4.60345 "	24487 "
	Jupiter		11.86 "	86560 "
	Saturn		29.46 "	290962 "
	Uranus		84.02 "	1176765 "
	Neptune		164.78 "	2888533 "

[1] The discussion from here on is substantially identical with that embodied in an article communicated to the *Astronomische Nachrichten* under date of January 1, 1909.

Sub-Systems.	Satellite.	R_0 Adopted Rotation of Planet.	P_0 Observed Period of Satellite.	R_0 Time of Planet's Rotation Calculated by BABINET'S Criterion.
Earth	The Moon	1 day	27.32166 days	3632.45 days
Mars	*Phobos*	24.62297 hrs.	7.6542 hrs.	190.62 hrs.
	Deimos		30.2983 "	1193.52 "
Jupiter	V	9.928 "	11.9563 "	64.456 "
	I		1.7698605 days	14.60 days
	II		3.5540942 "	36.900 "
	III		7.1663872 "	93.933 "
	IV		16.7535524 "	290.63 "
	VI		250.618 "	10768.8 "
	VII		265.0 "	11602.4 "
	VIII		930.73 "	61997.2 "
Saturn	Inner Edge of Ring	10.641 hrs.	0.236 day	0.6228 day
	Outer Edge of Ring		0.6456 "	2.383 days
	Mimas		0.94242 "	4.2902 "
	Enceladus		1.37022 days	7.0615 "
	Tethys		1.887796 "	10.822 "
	Dione		2.736913 "	17.751 "
	Rhea		4.517500 "	34.620 "
	Titan		15.945417 "	186.05 "
	Hyperion		21.277396 "	273.06 "
	Japetus		79.329375 "	1580.1 "
	Phœbe		546.5 "	20712. "
Uranus	*Ariel*	10.1112 hrs. (cf. *A. N.* 3992)	2.520383 "	33.714 "
	Umbriel		4.144181 "	65.435 "
	Titania		8.705897 "	176.05 "
	Oberon		13.463269 "	314.83 "
Neptune	Satellite	12.84817 hrs. (cf. *A. N.* 3992)	5.87690 "	141.8 "

Now the planets and satellites could be formed in but one of two possible ways: (1) They might conceivably have been detached from the central masses which now govern their motions, by acceleration of rotation, as supposed by LAPLACE. (2) They might have been original nuclei captured in the midst of the solar nebula, and afterwards gradually built up by the agglomeration of more cosmical dust, while at the same time the orbital motion in this resisting medium would have

reduced the major axes and eccentricities of their orbits and thus produced the near approach to perfect circularity now observed in our solar system.

We have, however, just proved, by the application of BABINET's criterion, based on the law of areas, that these bodies could not have been detached from the central masses about which they now revolve. *Accordingly it follows that they were all captured, and have since had their orbits reduced in size and rounded up under the secular action of the resisting medium formerly pervading the planetary system.*

From this unexpected conclusion there is absolutely no escape; for we may prove this by the following reasoning. The effect of a resisting medium in reducing the major axis and eccentricity of the orbit of the resisted body is fully recognized, and has been known for more than a hundred years. The formulæ for the changes of these two important elements may be reduced to the form

$$\delta a = -\frac{2a^2}{p^2(1+m)}[A' v + \text{periodic terms}] \quad . \; . \; . \quad (3)$$

$$\delta e = -\frac{2}{p}[Aev + \text{periodic terms}] \quad . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

where p is the parameter of the orbit, a the semi axis major, e the eccentricity, v the true anomaly, and m the mass of the resisted planet, and A and A' constants. As both of these expressions are negative, it follows that under the secular action of a resisting medium the major axis and eccentricity always decrease. In deriving these formulæ, however, the density of the resisting medium is supposed to increase towards the center, conformable to what is observed in the nebulæ and shown to result from the theory of gases.

LAPLACE himself has discussed this question with characteristic penetration in the *Mécanique Céleste* (Liv. X, ch. VII, § 19). He shows that when the density of the medium, represented by $\Phi\left(\frac{1}{r}\right)$ increases towards the Sun, the semi axis major and eccentricity always decrease; and finally remarks: "Therefore at the same time that the planet approaches towards the Sun, by the effect of the resistance of the medium,

the orbit will become more circular." It is surprising that it did not occur to the author of the *Mécanique Céleste* that the roundness of the orbits of the planets and satellites could be explained by a resisting medium quite as easily and simply as by the theory of a rotation which would gently detach these masses and set them revolving in orbits which are nearly circular, especially since the nebular hypothesis itself necessarily implies the existence of such a medium where the planets and satellites now revolve. LAPLACE merely remarks that if the nebula filled the whole of this space the bodies would encounter such resistance as to cause them to fall into the Sun; *but in making this statement he overlooked the fact that most of the nebulous matter did go into the Sun and planets, and it is from this circumstance that the central masses became so preponderant, while the attendant bodies are in all cases so very small.*

During a recent conference with my friend Professor GEORGE DAVIDSON, I mentioned LAPLACE's proof that a resisting medium had formerly acted against *Jupiter's* satellites I, II, III, to bring about a near approach to commensurability in their mean motions, and thus enable their mutual attraction to establish a rigorous relationship under the influence of this slowly acting cause. This venerable astronomer justly remarked: "LAPLACE had the true cause in sight, but he did not carry it far enough to discover the actual process by which the solar system was formed."

Evidently LAPLACE had not tested his nebular hypothesis by the criterion based on the conservation of areas, afterwards proposed by BABINET, and it simply did not occur to him that the circularity of the orbits pointed unmistakably to the secular action of a resisting medium. As the very existence of a nebula implies resistance to bodies revolving within it, this oversight is the more remarkable; and unfortunately not only was LAPLACE's reasoning vitiated, but an equally disastrous effect exerted on all other investigations in cosmical evolution for more than a century, because all mathematicians followed the same line of thought, on the false premise that the planets and satellites were detached from the central bodies which now govern their motions.

If in the light of this new theory of the shaping of the orbits under the secular effects of resistance we examine our solar system carefully we shall find many phenomena confirming the former existence of such a medium in our system.

It must suffice here to call attention to but a very few of the numerous survivals of the primordial resisting medium still shown by our system:—

(1) The rapid motion of *Phobos,* the inner satellite of *Mars,* which has been brought down near the planet by resistance, till it now revolves in less than a third of the time of the planet's rotation. It is true that Professor Sir G. H. DARWIN explains this motion of *Phobos* by a tidal retardation of the axial rotation of *Mars*, but in view of the large part undeniably played by the resisting medium in the formation of our system as a whole this explanation will not hold, though a very small part of the observed effect may be traceable to tidal friction.

(2) The famous inequality in the motions of the three inner Galilean satellites of *Jupiter,* which point unmistakably to a resisting medium, as was sagaciously pointed out by LAPLACE in 1796. His remarks on this subject are as valid and convincing as any which could be made to-day.

(3) The observed rapid motion of the inner ring of *Saturn,* which greatly exceeds the axial rotation of the planet. The rings evidently were never detached from the planet, but simply survive out of a much larger mass of cosmical dust which has been absorbed in building up the mass of *Saturn.* All the data in the table relative to BABINET'S criterion bear on this same question.

(4) The general fact that the satellite orbits are so round, and in general rounder and rounder the nearer we approach the planets, confirms the capture of these bodies in a medium which was denser towards these centers. The roundness of the satellite orbits shows that resistance was very effective from *Mars* to *Neptune,* and therefore no doubt throughout our whole solar system.

(5) The retrograde motion of *Saturn's* satellite *Phœbe* and *Jupiter's* eighth satellite is likewise to be explained by the capture of these bodies. Whatever may have been their orig-

inal eccentricities at the time of capture, even retrograde directed bodies could have survived, because the medium against which they revolved was of very slight density at that great distance from the planets. This slight density of the resisting medium at this distance is also indicated by the survival of considerable eccentricities in the orbits of these two satellites. The eccentricity of the orbit of *Phœbe* is given as 0.22, that of *Jupiter* VIII as 0.44, which are certainly anomalous enough to excite our suspicion. It is not by chance that retrograde motion in these two cases is associated with the highest eccentricities observed among all the satellites thus far discovered.

(6) The orbits of the asteroids have been gathered into their present positions mainly by the action of *Jupiter* and of the resisting medium. Originally they were more widely distributed over the whole system than at present; but even now they overlap the orbits of *Jupiter* and *Mars,* and there may be others of still wider range.

(7) The extreme roundness of the orbit of *Neptune* is a clear indication that this planet moved for a long time against a vast amount of nebulous resistance. Therefore it is very improbable that our planetary system terminates with *Neptune.* *In all probability there are several more planets beyond the present boundary of the system, some of which may yet be discovered.*

(8) The equatorial accelerations noticed on the globes of the Sun and of *Jupiter* and *Saturn* are to be explained by the falling in of matter revolving in vortices about these bodies. As the orbital motion of this matter near these bodies exceeds that depending on the axial rotation, the falling particles necessarily produce an equatorial acceleration. This process may still be going on; at any rate, it has been in progress so recently that the effects still continue.

(9) The solar system was formed from a spiral nebula, revolving and slowly coiling up under mechanical conditions which were essentially free from hydrostatic pressure. And spiral nebulæ themselves arise from the meeting of two or more streams of cosmical dust. The whole system of particles has a sensible moment of momentum about some axis, and

thus it begins to whirl about a central point, and gives rise to a vortex. In the actual universe the spiral nebulæ are to be counted by the hundreds of thousands, if not by the million, and it is evident that they all arise from the automatic winding up of streams of cosmical dust, under the attraction of their mutual gravitation. The two opposite branches of the spiral nebulæ, so often shown on photographs, represent the original streams of cosmical dust which are coiling up and forming gigantic spiral systems.

(10) When the nebula rotates and the coils wind up in such a way as to leave open spaces between the coils, or at least freedom from sensible hydrostatic pressure, the usual result is the development of a system made up of small bodies, such as the planets compared to the greatly preponderant Sun, or the satellites compared to the much greater planetary masses which control their motions. In the solar system where the conditions are accurately known this is proved to have occurred; and it was repeated so many times, always with uniform results, giving a large central mass and small attendant bodies, that the general law for this condition is clearly established.

(11) If the streams so converge that the nebulous mass becomes very concentrated at the center, so as to become a figure of equilibrium under the pressure and attraction of its parts, the nebula may divide into a double star, as I have elsewhere inferred from the researches of POINCARÉ and DARWIN on the figures of equilibrium of rotating masses of fluid.

(12) Now both of these forms of development, depending on variations of the two processes, are abundant in the actual universe, and probably almost all of the apparently single stars are surrounded by systems of planets. At least one fifth of all the stars are estimated to be double or multiple. If we assume the chances of the two forms of development to be equal we may calculate from the preponderance of small bodies actually found in the solar system—eight principal planets, twenty-five satellites (besides our Moon), and 625 asteroids—that the chances of a nebula devoid of hydrostatic pressure producing small bodies is about 2^{658} to 1, or a decillion decillion (10^{66}) to

the sixth power, to unity. This figure is so very large that we shall content ourselves with illustrating a decillion decillion, and for this purpose we avail ourselves of a method employed by ARCHIMEDES to illustrate his system of enumeration. Imagine sand so fine that 10,000 grains will be contained in the space occupied by a poppy seed, itself about the size of a pin's head; and then conceive a sphere described about our Sun with a radius of 200,000 astronomical units (α *Centauri* being at a distance of 275,000), entirely filled with this fine sand. The number of grains of sand in this sphere of the fixed stars would be a decillion decillion (10^{66}). All these grains of sand against one is the probability that a nebula devoid of hydrostatic pressure such as that which formed the planets and satellites will lead to the genesis of such small bodies revolving about a greatly predominant central mass.

This is a very brief and inadequate outline of a few of the leading points in a very large investigation with which I have been occupied. Most of these results were established over six months ago, and I have had opportunity to discuss them with several experienced astronomers. It is hoped that the whole investigation may appear as Volume II of my "Researches on the Evolution of the Stellar Systems"; but it seemed advisable to communicate this brief summary of some of the most interesting points without further delay.

The effect of this work will be to give the theory of the resisting medium the highest importance in all researches relating to the history of the universe. It is very remarkable that the principal secular effects of this cause are exactly opposite to those due to tidal friction as investigated by DARWIN. For while tidal friction usually increases the major axis and eccentricity of an orbit, the resisting medium as regularly decreases both of these elements. In the actual physical universe both causes are at work together, sometimes one influence predominating and then the other. Resisting medium is relatively most effective in a system made up of a large central sun, and small attendant bodies such as the planets of our solar system, and in the systems of satellites dominated by large planets. Tidal friction is most effective in systems made up of two large masses, such as the double stars.

It has seemed important to call attention to the cause of the roundness of the orbits of the planets and satellites, because it appears likely that the criteria now introduced may go far toward clearing up the mystery which has always surrounded the origin of the solar system.

In all the celebrated speculations of the distinguished astronomers who have occupied themselves with the genesis of our solar system, four phenomena have ever been foremost: (1) The great circularity of the orbits; (2) The small inclinations and the common direction of the orbital motion; (3) The smallness of the attendant planets and satellites compared to the large central masses which govern their motions; (4) The regularity and order everywhere found in our system, the distances, masses, and mutual relations of the orbits being such as to secure maximum stability and perpetuity. All these phenomena and many others are now perfectly explained by a simple theory, which also conforms to the laws of spiral development observed in the sidereal universe. A simple and obvious theory which accounts for the known phenomena while all other theories are involved in contradiction, will naturally have a strong claim to acceptance. Indeed we cannot refuse our assent to it without violating the recognized rules of natural philosophy as formulated by NEWTON in the *Principia*.

U. S. NAVAL OBSERVATORY,
MARE ISLAND, CAL., January 30, 1909.

PHOTOGRAPHS OF COMET *c* 1908 (MOREHOUSE).

BY A. ESTELLE GLANCY.

From September 19th until December 15th, at which latter date the comet could be followed only long enough to photograph the head, exposures have been made at the Lick Observatory on every favorable occasion. Successful exposures were made on twenty-eight nights. The nights omitted were unfavorable,[1] by reason of too strong moonlight, clouded sky, or

[1] The number of unfavorable nights was unusually large this year.

high winds. The Crocker photographic telescope was used in this work. This instrument carries two cameras,—a Willard lens of 15.2^{cm} (6.0 inches) aperture and 78.28^{cm} (30.82 inches) focal length, and a Dallmeyer lens of the same aperture and 82.6^{cm} (32.52 inches) focal length. Hence the scale value of the plates taken with the Willard lens is $1° = 1.37^{cm}$ (0.538 inch) and that of the Dallmeyer is $1° = 1.44^{cm}$ (0.568 inch). As soon as the comet had increased sufficiently in brightness to allow of a reasonably short exposure time, it was planned to use the Willard camera for one plate of fairly strong density, and simultaneously to expose in the Dallmeyer camera two plates, each of one half the exposure time with the Willard camera. By this arrangement each camera was made to serve a different purpose. The Willard plate gives a strong image of the general appearance of the comet, including the fainter portions of the tail; the Dallmeyer plates give more truthfully the actual conditions existing at a given time and permit comparisons to determine the motions of condensations or other details of structure in the tail of the comet. It has been recognized for several years that intervals of twenty-four hours are too long to detect the rapid transformations which take place in comets; and a superficial examination of the Willard plates shows this to be particularly true of Comet Morehouse. So different are some of these plates from the one taken on the preceding or the following day that no indications of identity are visible at first sight.

Below is a tabulation of the series of Lick Observatory plates, which may be of service to observatories in other longitudes:—

Pacific Standard Time. 1908.	Willard Camera. Middle of Exposure.	Willard Camera. Duration.	Dallmeyer Camera. Middle of Exposure.	Dallmeyer Camera. Duration.
Sept. 19.	$10^h\ 28^m$	$3^h\ 0^m$	$10^h\ 28^m$	$3^h\ 0^m$
27.	9 33	1 30	9 33	1 30
27.	12 40	1 30	12 40	1 30
29.	8 56	1 32	8 56	1 32
29.	11 20	1 30	12 8	3 5
29.	12 54	1 29	.. ..	.. ..

Pacific Standard Time. 1908.		Willard Camera. Middle of Exposure.		Willard Camera. Duration.		Dallmeyer Camera. Middle of Exposure.		Dallmeyer Camera. Duration.	
Oct.	16.	10	20	1	38	9	54	0	47
		..	..	..	..	10	45	0	48
	18.	7	58	1	31	7	58	1	31
	20.	9	27	2	44	8	45	1	20
		..	..	..	..	10	9	1	20
	21.	8	12	2	46	7	30	1	22
		..	..	..	..	8	54	1	21
	22.	10	0	2	35	9	19	1	12
		..	..	..	..	10	38	1	20
	23.	8	12	2	44	7	28	1	16
		..	..	..	..	8	51	1	26
	24.	8	8	2	44	7	24	1	16
		..	..	..	..	8	47	1	26
	25.	8	26	2	21	7	24	1	15
		..	..	..	..	8	50	1	34
	26.	7	6	0	36	7	6	0	36
	27.	8	50	2	49	8	10	1	15
		..	..	..	..	9	34	1	22
	28.	..	..	..	..	8	46	1	1
		..	..	..	..	9	54	1	13
	30.	10	25	1	16	10	2	0	30
		..	..	..	..	10	40	0	45
Nov.	10.	6	58	1	5	6	46	0	45
		..	..	..	..	7	20	0	20
	11.	6	52	1	32	6	28	0	45
		..	..	..	..	7	16	0	45
	12.	7	57	1	54	7	25	0	50
		..	..	..	..	8	26	0	57
	13.	7	37	1	42	7	11	0	50
		..	..	..	..	8	3	0	50
	14.	7	6	1	40	6	41	0	50
		..	..	..	..	7	33	0	46
	15.	7	5	2	10	6	25	0	50
		..	..	..	..	7	38	1	4
	16.	7	21	2	42	6	25	0	50
		..	..	..	..	7	31	1	0
		..	..	..	..	8	22	0	40

Pacific Standard Time. 1908.	Willard Camera. Middle of Exposure.		Duration.		Dallmeyer Camera. Middle of Exposure.		Duration.	
Nov. 17.	7	24	2	43	6	28	0	50
	..	..	..	..	7	22	0	55
	..	..	..	..	8	20	0	53
18.	7	1	1	52	6	30	0	50
	..	..	..	..	7	27	1	0
27.	7	16	1	8	7	16	1	8
28.	7	10	0	44	7	10	0	44
Dec. 10.	6	24	0	29	6	24	0	29
11.	6	27	0	22	6	27	0	22
12.	6	21	0	24	6	21	0	24

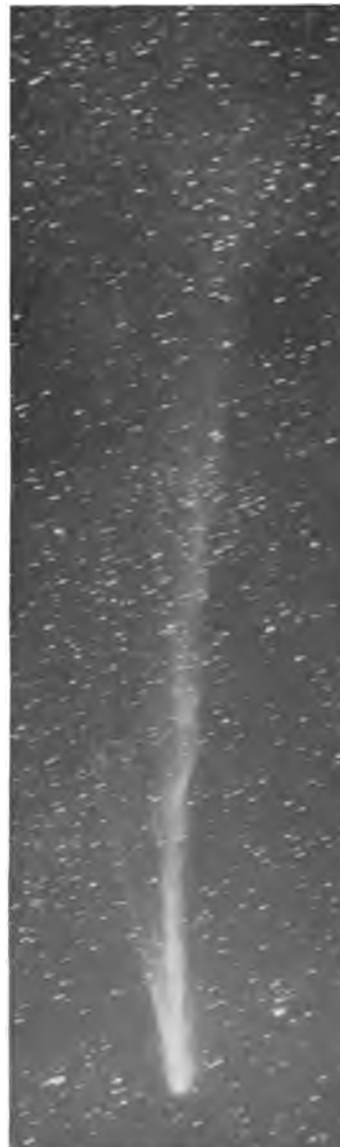
The four photographs selected for reproduction were chosen because of their striking appearance. The first and fourth belong respectively to the earlier and later half of the period under observation; the second and third occurring near the middle of the series, demonstrate the changes which may be expected in two days. Since no reproduction by mechanical processes can do justice to the original negatives, a description of these four plates is given to supplement the illustrations.

October 24th.—The comet appears on this date in one of its quieter phases. In the line of strongest expulsion from the head is a long, narrow, dense streamer. On the following side, a broad, heavy streamer extends about 4°.6. On the preceding side, a like streamer of greater density and breadth extends out to 10°. About 3° from the extremity there is a sharp bend in the same direction in which the radius vector[1] is moving. There are two undulations about 2° from the head, and a noticeable bulging at a distance of about 4°.5. Faint line-streamers and one fan-shaped streamer lie outside the main tail. The activity in the head is seen to continue well around on the side toward the Sun.

November 16th.—This plate is one of a group showing very rapid changes. The tail belongs to the type frequently noticed, a central helical structure and outlying, long, narrow streamers. The general direction of the tail is one of continued

[1] The radius vector is the line joining the Sun and comet. As the comet moves in its orbit this line moves forward also.

Nov. 16, 1908. 7h 21m P. S. T.



Nov. 18, 1908. 7h 1m P. S. T.

Comet C 1908 (Morehouse).

curvature for about 7°. The curvature shows that the tail is lagging behind the radius vector. From 7° to 11° the tail is bent in the opposite direction. The breadth of the tail is due to many diffuse and divergent faint streamers. The matter which is puffed out, as it were, appears to come from the sharp apex of a cone. The clear-cut edges of the cone are outlined by single streamers. Within the cone is a dense, wavy streamer which inclines toward the following side of the cone for about 1°, and then shifts to the opposite side, breaking out into the more pronounced spiral structure. The spiral increases in dimensions until it is finally broken up by the diffusion of the matter composing it. One is reminded of the extraordinary outburst which occurred on October 15th on a larger scale. One fine streamer within the cone appears distinctly severed; the broken ends are thrust far apart. It is worth noticing that the heavy bright streamer whose outer extremity is about 5° from the head, and whose inner extremity appears to be disconnected from the main tail, has appeared within twenty-four hours. No streamer on the plate of November 15th can be identified with it. Short, straight, and more divergent streamers define the boundaries of the tail near the head. The head itself is unusually small, showing both nucleus and coma.

November 18th.—In general appearance this plate resembles that of November 17th, but only in type, for there are no points of identity immediately recognizable. Nearly all the matter composing the tail seems to lie in a well-defined cone with an angle of about 21°. The central portion is very bright and of varying density. The outer parts are composed of many line-streamers, the greater number of these lying on the preceding side. The spiral structure is not so definitely suggested on this plate as on some of the other plates. The source of the densest stream of matter seems to be the well-defined apex of a smaller cone within the cone mentioned above. A large-scale plate might prove this to be an apparent rather than a real effect. The general direction of the tail shows that it is lagging behind the radius vector. On the following side the streamers are few and relatively short, thus leaving a boundary defined by the brightest portions of the tail. On the preced-

ing side the streamers diverge at an unusually large angle from the main tail. On November 17th a similar group of streamers was prominent, but the deviation from the main direction was less. It should be noted that parts of the main tail and the outlying streamers often have corresponding irregularities of structure. The head appears larger than on November 16th, and is active over the greater part of its circumference.

November 27th.—The definition of the photograph is marred by fogging, due to strong moonlight, but what I have called the spiral structure is so well marked that this plate was chosen in preference to other more perfect ones. The tail structure is like that of November 16th. Within the numerous divergent streamers is a narrow cone of luminous matter. About 0°.4 from the head it bulges and the wavy streamers (perhaps there is but one, which is very erratic) appear to shoot out in a conical helix, which is finally dissipated in a broad diffuse flare.

Such a wealth of like data has been gathered by many observers in America and Europe that an unusually complete history of the comet's behavior may be constructed. Certainly no earlier comet has been subjected to such exhaustive observations. Photography finds an important usefulness in comet work, and Comet Morehouse is a remarkably favorable subject for two reasons. In the first place, the orbit plane could scarcely be better situated with respect to the Earth. With an inclination of 140° to the ecliptic, it cuts the equator a little east of the winter solstice, and the point of perihelion passage lies but a little south of the equator. Perihelion passage occurred on December 26th. Hence, from September 1st to December the comet was visible in the northern hemisphere, and during the early part of this period it was a circumpolar object. Five weeks after its disappearance below our horizon it became visible to the southern observers under almost as favorable circumstances, and it can be followed for several months more. Though visually fainter than Comet Daniel 1907, Comet Morehouse photographed more readily. This is due to the fact established by spectroscopic observations here and elsewhere, that the radiations lying in the visual regions

of the spectrum (red, orange, yellow, green) are weak and those in the photographic regions (blue and violet) are remarkably strong. Hence this comet, which appears in the visual telescope as an object of little interest, has secured the continuous attention of numerous observers.

Several months still remain in which material for study will be collected, and it is too early to know the results of the evidence already at hand. But it is believed that the photographic records of the comet's behavior will increase greatly our general knowledge of comets and bear especially strongly upon present theories regarding tail formation.

Extensive series of photographs have been taken by the observers at Greenwich, by M. QUÉNISSET and M. BALDET at the observatory of Juvisy, and by Professor BARNARD at Williams Bay. And no doubt the German observers and others have been photographing the comet. Extraordinary outbursts were recorded by one or more observers on or about September 16th and 30th and October 1st, 6th, and 15th. It is regretted that because of less favorable weather, none of these dates are included in the Lick Observatory series.

However, perhaps occasional astonishing transformations show no more remarkable cometary activity than the less conspicuous and more frequent developments. And it is probable that the recurrent types of activity will help most in the solution of the problem of tail formation. An early statement on this subject is made by the Astronomer Royal of England in connection with a preliminary examination of the Greenwich plates.[1] He says: "A study of the photographs shows that the form of the comet's tail exhibits a recurring series of phases, and that the phase seems to bear a relation to the condition of the nucleus which passes through cycles of stages of alternating activity and quiescence. At the stage of quiescence the comet presents the appearance of a nucleus with little enveloping coma, and straight streamers passing away at little inclination to the general direction of the tail. The coma then grows, envelopes form about the nucleus (on the side towards the Sun), and the rays of the tail become more spread. The stage of maximum activity is now reached, and

[1] *Monthly Notices R. A. S.*, **69**, 52, 1908.

larger quantities of matter appear to be expelled from the head and then driven back, forming a bright wavy tail, the streamers being no longer straight, but greatly disturbed. The bright tail then appears to be driven off and the stage of quiescence follows."

The presence of parabolic envelopes about the nucleus, such as have been seen in the large comets, is well established by the Greenwich plates. It is interesting to know that so complete is the Greenwich series of photographs that the development of these envelopes into straight rays can be watched and that the physical changes in the tail can be followed. The series of plates on which are shown the details of the coma and that portion of the tail near the head were made with the reflecting telescope of thirty inches' aperture and are, therefore, large-scale photographs. Before the above-quoted article was read, one of the Lick Observatory plates was noticed to show traces of a parabolic envelope, but so uncertain was the appearance that it was considered to be possibly only a photographic effect.

Other facts about the Lick Observatory photographs are equally interesting. Perhaps the most striking fact is the frequent occurrence of that type of tail structure which is shown in three of the illustrations. It appears as if the tail were more or less irregularly cone shaped, a skeleton conical surface being formed by long, comparatively straight shafts of luminous matter ejected from a small area of the nucleus. Having the same axis and smaller conical dimensions, there appears to be a helix of dense matter which, receding from the nucleus, expands from a tightly compressed stream into a diffuse spiral until the structure is lost in the dissipation of the material forming it. This action has been likened by Dr. CAMPBELL to the flame from a waving torch.

An interesting group of plates falls between the dates November 13 and November 18, inclusive. One image of the comet is entirely different from the next one, but of recurrent type. More resemblance exists between two plates of forty-eight hours' interval than between an intervening plate and either of these two. Long, bright streamers appear and disappear in twenty-four hours. For instance, the long streamer

$5°$ in length in the illustration of November 16 appeared subsequent to the exposure of November 15. At any rate, there is no streamer on the earlier plate with which it can reasonably be identified. If we assume that matter has been ejected to a distance of $5°$ in one day, the average velocity of recession from the nucleus is greater than ninety miles per second, for ninety miles per second is roughly the velocity in the direction of the tail projected upon a plane at right angles to the line of sight. That the phenomenon is an effect of rotation is also difficult to conclude. Photographs taken at other observatories during this interval would help solve the problem.

Without doubt, the comparison of plates will show acceleration in the motion of recession from the head. One such rough measure has been made from a reproduction of a photograph[1] taken at the Observatory of Juvisy on October 16th, 7^h 45^m, Paris Mean Time, and two photographs taken at the Lick Observatory, October 16th, 10^h 20^m, and October 18th, 7^h 58^m, Pacific Standard Time. Approximate measures were made on the broadening of the tail. The distances on the three plates are $1°.5$, $1°.9$, and $4°.3$. The resulting average velocities of recession from the head in the direction of the tail are twenty-seven miles (44^{km}) and thirty-six miles (58^{km}) per second for the first and second intervals, respectively.

Much work remains to be done, and the detailed results will be published in a subsequent *Lick Observatory Bulletin*.

LICK OBSERVATORY, January 28, 1909.

[1] *Comptes Rendus*, **147**, 1035.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1909.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon.....May 5,	4^h 8^m A.M.		Full Moon....June 3,	5^h 25^m P.M.
Last Quarter... " 12,	1 45 P.M.		Last Quarter... " 10,	6 43 P.M.
New Moon.... " 19,	5 42 A.M.		New Moon.... " 17,	3 28 P.M.
First Quarter.. " 26,	5 28 P.M.		First Quarter.. " 25,	10 43 A.M.

There will be two eclipses during June.

The first is a total eclipse of the Moon on June 3d, and it will be visible in part at least over the United States, except the extreme western portion. For the extreme eastern states total eclipse begins shortly before sunset, while for the states along the Pacific Coast the eclipse will be about ended at sunset.

The second is a central eclipse of the Sun on June 17th, the line of central eclipse running from Siberia across the Arctic Ocean and south through Greenland. On the central line it is an annular eclipse at the beginning and end of its path and a total eclipse in the middle part. It will be visible as a partial eclipse in the late afternoon throughout the United States, except that part south of a line running from San Francisco southeast into the Gulf of Mexico. The local times for beginning and end at Ogden, Utah, are 4^h 48^m P.M. and 6^h 3^m P.M.

The summer solstice, the time when the Sun reaches its most northerly point, occurs June 21st, 6^h P.M., Pacific time.

Mercury passed superior conjunction with the Sun on April 1st and became an evening star, and will remain an evening star until June 14th, when it passes inferior conjunction and becomes a morning star. The month of May affords the best time of the present year for seeing the planet. On May 1st the interval between the setting of the Sun and of the planet is just about one hour, and this interval rapidly increases as

the planet moves out toward greatest east elongation. It is increased by the circumstance that the planet is in the northern half of its orbit, reaching greatest heliocentric latitude on May 9th. By the middle of the month the planet does not set until nearly two hours after sunset. Greatest eastern elongation is reached on May 20th. The distance from the Sun is then 22° 23′, about an average greatest elongation. After greatest elongation the planet and Sun approach each other, but on June 1st the planet will not set until an hour and a quarter after sunset. It will therefore still be visible in the early days of June. After passing inferior conjunction on June 14th the distance between planet and Sun increases rapidly, so that by the end of the month the planet rises about an hour before sunrise.

Venus became an evening star on passing superior conjunction April 28th, and will remain an evening star until after the close of the year. On May 1st it sets only two minutes after sunset and remains too near the Sun for naked-eye visibility until after the middle of the month, and until the middle of June it sets less than an hour after sunset. It will not be a conspicuous object until autumn.

Mars rises at about $1^h\ 40^m$ A.M. on May 1st, and at about $11^h\ 30^m$ P.M. on June 28th. It moves about 36° eastward and 12° northward, from *Capricorn* through *Aquarius* into *Pisces*. Its distance from the Earth diminishes from 104,000,000 miles on May 1st, to 64,000,000 on June 30th, and its brightness nearly trebles during the two months. It is, however, at the end of June only one third as bright as it will be at opposition in late September.

Jupiter is in fine position for evening observation, being above the horizon on May 1st until about $2^h\ 30^m$ A.M. It sets earlier as the month advances, but remains above the horizon as late as $10^h\ 40^m$ P.M. on June 30th. It is stationary among the stars on May 1st, but begins to move slowly eastward, gradually increasing its rate until by the end of June it is nearly 5° east and 2° south of its position on May 1st.

Saturn became a morning star early in April. By May 1st it rises not quite an hour before sunrise, and by June 30th it rises about half an hour after midnight. It is in the constel-

lation *Pisces* and moves about 5° east and 2° north during the two months.

Uranus rises shortly after midnight on May 1st, and shortly after 8^h P.M. on June 30th. It is in *Sagittarius,* east and north of the bowl of the "milk-dipper," and moves somewhat more than 1° westward during the period.

Neptune is in *Gemini* and is in the western sky in the evening. *Venus* passes a little less than 2° north on the evening of June 22d.

NOTES FROM PACIFIC COAST OBSERVATORIES.

ORBITS OF THE BINARY STARS 55 *TAURI*, π^2 *URSÆ MINORIS*, AND 4 *AQUARII*.

The orbit of 55 *Tauri* (= OΣ 79) was first computed by HUSSEY in 1901, but at that time there was still great uncertainty as to the form of the apparent ellipse, and the one on which his elements were based will not fit the more recent observations. The range of uncertainty is now much smaller, and it is hoped that the following elements will prove to be approximately correct. They are:—

True Elements.	Apparent Orbit.
$P = 96.3$ years	Length of major axis = 0″.92
$T = 1898.0$	Length of minor axis = 0″.51
$e = 0.65$	Distance of star from center = 0″.23
$a = 0.54$	Position-angle of major axis = 48°.0
$\Omega = 77°.3$	Position-angle of periastron = 205°.8
$i = \pm 55.3$	
$\omega = 114.35$	
Angles increasing.	

No orbit has heretofore been published of the binary star π^2 *Ursæ Minoris* (= Σ 1989), although the angular motion since discovery in 1832 exceeds 270°. This is mainly due to the uncertainty attaching to the early observations. The following elements give satisfactory residuals for these observations, as well as for the more reliable of my recent measures made when the angular separation of the two components was less than 0″.10. Nevertheless the results must be regarded as subject to a large degree of uncertainty. They are:—

True Elements.	Apparent Orbit.
$P = 115$ years	Length of major axis $= 0''.82$
$T = 1902.7$	Length of minor axis $= 0''.24$
$e = 0.80$	Distance of star from center $= 0''.33$
$a = 0''.42$	Position-angle of major axis $= 11^\circ.45$
$\Omega = 16^\circ.3$	Position-angle of periastron $= 189^\circ.2$
$i = \pm 62.25$	
$\omega = 165.0$	
Angles decreasing.	

The following orbit of 4 *Aquarii* ($= \Sigma$ 2729) was computed in 1905, because of the very large residuals resulting from the comparison of my measures with SEE's elements. They were not published at that time, however, because of the uncertainty introduced by the discordance of the early measures. Since then LEWIS has published an orbit with nearly the same period as that here given, but with different geometric elements. For this reason it seems desirable to place my results on record, especially as they represent the measures of the past four years within the limit of error of measurement. They are:—

True Elements.	Apparent Orbit.
$P = 135.6$ years	Length of major axis $= 1''.21$
$T = 1899.8$	Length of minor axis $= 0''.57$
$e = 0.35$	Distance of star from center $= 0''.12$
$a = 0''.64$	Position-angle of major axis $= 165^\circ.4$
$\Omega = 164^\circ.8$	Position-angle of periastron $= 221^\circ.2$
$i = \pm 62.3$	
$\omega = 73.3$	
Angles increasing.	

More detailed accounts of these investigations will be published later.

R. G. AITKEN.

March, 1909.

THE PERIOD OF *β CANIS MAJORIS*.

An extensive series of spectrograms of *β Canis Majoris* has been obtained. This star was announced as a spectroscopic binary a few months ago. The period of velocity variation is very close to six hours. This star, therefore, has a shorter

period than any other known spectroscopic binary except *β Cephei*. The period of *β Cephei* was found by FROST to be $4^h\ 34^m.2$.

The velocity of *β Canis Majoris*, reduced to the Sun, varies between $+23^{km}$ and $+42^{km}$ per second. The interval between greatest positive and greatest negative velocity is two and a half hours. It is fortunate that the star is bright (2.6 phot. mag.). In fair seeing, and with a slit-width of 0.0013 inch, an exposure of eighteen minutes produces a well-exposed spectrogram. If an exposure of two hours had been required, the binary character of this star might easily have escaped detection.

It is not impossible that some of the fainter stars having broad and fuzzy lines are spectroscopic binaries of short period. On such stars it will be necessary to reduce the exposure time as much as possible, by using a wide slit and probably also a low dispersion.

SEBASTIAN ALBRECHT.

February, 1909.

THE VISIBILITY OF MT. WHITNEY FROM MT. HAMILTON.

In a note in No. 124 of these *Publications*, I stated my reasons for thinking that Mt. Whitney was visible from Mt. Hamilton. Professor WRIGHT has made some further investigations and computations on this matter and concludes that it is not Mt. Whitney but the Kaweah Peaks which I have observed.

The identification of Mt. Whitney in my note depends to a great extent on the computed bearing, which appears to be in error by a sufficient amount to make it coincide with the observed bearing of the Kaweah Peaks, and that Mt. Whitney is in reality just obscured by Milestone Peaks and the ridge which extends from them to the southwest.

April 2, 1909. C. D. PERRINE.

LECTURES AT BERKELEY.

The following course of lectures was given during the present semester before the class in Modern Astronomy at the University of California:—

Dr. JOSEPH H. MOORE, Assistant Astronomer Lick Observatory—Thursday, March 18th, and Saturday, March 20th. Subject, "Periodic Variable Stars."

Dr. GEORGE E. HALE, Director Mt. Wilson Solar Observatory—Saturday, March 27th. Subject, "Solar Vortices and Magnetic Fields."

Dr. R. G. AITKEN, Astronomer Lick Observatory—Tuesday, March 30th; subject, "Comets." Thursday, April 1st; subject, "Visual and Spectroscopic Binary Stars."

R. T. CRAWFORD.

RESIGNATION OF ASTRONOMER PERRINE.

Dr. CHARLES DILLON PERRINE, of the Lick Observatory staff, has been appointed Director of the Argentine National Observatory at Cordoba, in succession to the late Dr. THOME. Dr. PERRINE left Mount Hamilton on March 29th, *en route* to Cordoba.

Dr. PERRINE's astronomical career has been a remarkable one in many particulars. Prevented by circumstances from securing an academic education, he nevertheless looked forward to engaging in astronomical work. Resigning an important commercial position in 1893, he came to the Lick Observatory in the capacity of Secretary, with the fixed purpose of devoting his spare time to the study of astronomical and related subjects, by way of preparation for later observatory duties. In 1895 his title was changed to Secretary and Assistant Astronomer. He was appointed Astronomer in the Lick Observatory in 1905. His first successes, the discovery of thirteen comets (1895 to 1900), were made as a result of systematic searches undertaken outside of his assigned duties. Dr. PERRINE was awarded the Lalande Prize of the Paris Academy of Sciences in 1897, and the gold medal of the Mexican Astronomical Society in 1905. He was elected Associate of the Royal Astronomical Society in 1904. He received the degree of Doctor of Sciences from Santa Clara College in 1905.

The writer recognizes with pleasure that Dr. PERRINE's contributions to our knowledge of comets, of satellites, of solar eclipse phenomena, of nebulæ and star clusters, of solar

parallax, etc., are important factors in the history of the Lick Observatory. He regrets,—giving expression to only one of many feelings,—that he and Dr. PERRINE, who have observed three eclipses together, will probably not be able to observe a fourth eclipse in common again. It is a great satisfaction, however, to know that Dr. PERRINE'S experience and skill, acquired in the Lick Observatory, will be devoted to the development of astronomy in the southern hemisphere.

The sentiments of the Observatory community concerning the departure of Mr. and Mrs. PERRINE were expressed through the presentation of a loving-cup.

W. W. CAMPBELL.

GENERAL NOTES.

Variation of Latitude.—In the *Astronomische Nachrichten* No. 4287 Dr. ALBRECHT publishes an article giving provisional results of the International Latitude Service on the southern parallel during the interval 1906.4 to 1908.4. The programme of work for the southern parallel is similar to that of the northern parallel and the chief interest in the results centers about the z-term, which represents that part of the variation which is independent of the longitude of the place of observation, and which, at one time, was thought to be due to a periodic movement of the center of gravity of the earth along the axis of rotation. The observations show this term to have practically the same value for the southern parallel as for the northern, which shows that the above-mentioned hypothesis cannot be a true one. There is a phase difference of about one tenth of a year between the two values of the z-term, but the number of observations made on the southern parallel is not sufficiently great to demonstrate the reality of this part of the phenomenon.

Dr. ALBRECHT makes the statement that the observations at Bayswater, Australia, would be discontinued at the end of January, 1909. The work at Oncativo, however, was taken over by the Argentine Republic in July, 1908, and will be continued for an indefinite length of time. S. D. T.

Notes from "Science."—Mr. R. JAMES WALLACE, who has for several years past been engaged in photographic research at the Yerkes Observatory, as instructor in photophysics, has resigned his position there to become director of the research laboratory of the Cramer Dry Plate Company, of St. Louis. It is a promising evidence of appreciation of research that a commercial company engages the services of a scientific investigator for the improvement and further development of its products.

Dr. GEORGE E. HALE, of the Solar Observatory of Mount Wilson, has been appointed a delegate to represent the National Academy of Sciences at the Darwin Celebration at Cambridge.

Solar Eclipse.—In *Monthly Notices*, November, 1908, Dr. DOWNING gives details of the total solar eclipse of 1911, April 28, at Neiafu, on Vavau Island, in the South Pacific. The meteorological conditions are only fairly promising.

Professor W. W. PAYNE has retired, under the Carnegie Foundation, from the directorship of the Goodsell Observatory of Carlton College, and is succeeded by Dr. H. C. WILSON. Professor PAYNE still retains the ownership and editorship of *Popular Astronomy*.

Professor E. BECKER, Director der Kaiserlichen Universitätes Sternwarte zu Strassburg, has been made professor emeritus and has been succeeded by Professor J. BAUSCHINGER, Director des Astronomischen Recheninstituts in Berlin.

Dr. SIDNEY D. TOWNLEY, of Leland Stanford Junior University, was recently promoted to an associate professorship in applied mathematics.

Astrophysics, Proposed Professorship at Cambridge.—The Council of the Senate report that they have had under their consideration the position of the study of astrophysics in the university, in connection with the offer of the Royal Society to give to the university the equipment of Sir WILLIAM HUGGINS's observatory.

The study of astrophysics, which is growing rapidly and resulting in large accessions to knowledge, has a special interest for the University of Cambridge, from the fact that it is so intimately associated with the work of Sir GEORGE STOKES on the meaning of the Fraunhöfer lines in the solar spectrum. In 1889 the late Mr. R. S. NEWALL gave to the university a large refracting telescope specially adapted for the study of stellar physics, and the sole charge of this telescope was entrusted to his son, Mr. H. F. NEWALL, under conditions which he generously accepted. For the last eighteen years the work of the department has been most successfully carried out by Mr. H. F. NEWALL, and important scientific results have been obtained. In 1905 the department was strengthened by the McClean bequest of £5000 for the provision of improved instrumental equipment for the Newall observatory, and now the possession by the university of the instruments used by Sir WILLIAM HUGGINS will further increase the means of observation at the disposal of the department.

In 1907 an assistant in astrophysics was appointed for five years, who is paid £100 a year by the university and £100 a year by Mr.

NEWALL. The university is fortunate in having for so long a time had the advantage of the gratuitous and most generous services of one who stands in the front rank of astrophysicists, and Mr. NEWALL'S eminence in the study is undoubtedly one of the reasons which prompted the Royal Society—at the suggestion, as the council understand, of Sir WILLIAM HUGGINS himself—to make their recent offer.

The Council of the Senate are of opinion that the time is opportune for giving further recognition in Cambridge to astrophysics. They have consulted the General Board of Studies, and with their approval desire to recommend to the Senate the establishment of a professorship of astrophysics, without stipend, and limited to the tenure of office of the first professor, in accordance with Statute B. The Council recommend accordingly.—*London Standard.*

Royal Astronomical Society.—The annual meeting of the Royal Astronomical Society was held at Burlington House February 12th, Mr. H. F. NEWALL, the president, occupying the chair.

The president, on behalf of the members, extended a cordial welcome to Professor O. BACKLUND, Director of the Observatory, Pulkowa, Russia, to whom the society's gold medal had been awarded for his researches concerning the comet which was first observed in 1786, and has borne the name of Encke since that astronomer in 1819 established its periodicity. Professor BACKLUND had calculated the perturbations from 1819, and had demonstrated that the motion of the comet was constant to 1858, and then, after having diminished, was again constant during the period between 1851 and 1891. He had given an interesting account of the value of the forces opposing the motion of the comet, and had applied himself to a difficult branch of research with a measure of devotion and success which made it the desire of the society to express its admiration of his scientific achievements. Amid loud cheers the president handed the gold medal to Professor BACKLUND.

The Jackson-Gwilt bronze medal and gift were handed to Mr. P. MELOTTE, of the Royal Observatory, Greenwich, in recognition of his discovery of the eighth satellite of *Jupiter.*

The president, in an address, suggested for consideration the question whether the main characteristics of the spectroscopic phenomena of the Sun and stars are dictated mainly by matter constantly streaming in upon them, and not by matter within them.

A ballot resulted in the election of Sir DAVID GILL as president of the society for the coming year.—*London Times.*

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Memoirs of the Royal Astronomical Society. London. 1908. 4to. Boards.

Vol. LVII, Part III, Tables for computing standard co-ordinates on photographic plates. ARTHUR R. HINKS. 13 pp.

Vol. LVII, Part IV, Proper motions of faint stars in the Pleiades. F. J. M. STRATTON.

Double-star observations, 1902-1907. WILLIAM H. MAW. 32 pp.

Appendix II to Vol. LVII, The distribution of blue-violet light in the solar corona on August 30, 1905, as derived from photographs taken at Kalaa-es-Senam, Tunisia. 32 pp., with two plates.

Vol. LVIII, Observations of thirty-one variable stars. N. R. POGSON. 142 pp.

Vol. LIX, Part I, Theory of the motion of the Moon; containing a new calculation of the co-ordinates of the Moon in terms of the time. Part V. ERNEST W. BROWN. 103 pp.

Vol. LIX, Part II, Second index catalogue of nebulæ and clusters of stars; containing objects found in the years 1895 to 1907, with notes and corrections to the new general catalogue and to the index catalogue for 1888-1894. J. L. E. DREYER. 93 pp.

NYRÉN, M. Ascensions droites moyennes de 396 étoiles pour l'époque 1900.0. St. Pétersbourg. 1908. Folio. 12 pp. Paper.

Déclinaisons moyennes de 1375 étoiles pour l'époque 1900.0. St. Pétersbourg. 1908. Folio. 66 pp. Paper.

Observations faites au cercle méridien en 1907. Observatoire d'Abbadia. Hendaye. 1908. Folio. 349 pp. Paper.

Observatoire d'Alger. Catalogue photographique du ciel. Paris. 1908. Folio. 214 pp. Paper.

Parallaxenbestimmungen an dem Repoldschen Heliometer der Leipziger Sternwarte. B. PETER. Leipzig. 1908. 4to. 14 pp. Paper. Price, 80 pfg.

Publikationen des astrophysikalischen Observatoriums zu Potsdam. Potsdam. 1908. Folio. Paper.

Photographische Himmelskarte. Zone $+31°$ bis $+40°$ Deklination Katalog. Ergänzungen und Berichtigungen zu den Bänden I-IV. A BIEHL. 34 pp.

Nr. 46, Fünfzehnten Bändes, zweites Stück, Untersuchung über das 80^{cm} Objecto des Potsdamer Refraktors. J. HARTMANN. Mit 44 Figuren im Text und 11 Tafeln. 106 pp.

Nr. 59, Zwanzigsten Bandes, zweites Stück, Katalog von Doppelsternen der photographischen Himmelskarte aus der Zone von $+31°$ bis $+40°$ Deklination. J. SCHEINER. 43 pp.

STRUVE, HERMANN. Beobachtungen des Saturnstrabanten *Titan* am Königsberg und Berliner Refractor. Berlin. 1908. 4to. 44 pp. Paper.

Tablas para el cálculo de conjunctiones geocéntricas de las satélites de *Júpiter*. Don SALVADOR GARCIÁ FRANCAS y Don PEDRO CHARLO y JUSTO. San Fernando. 1908. 4to. 27 pp. Boards.

Transactions of the International Union for Co-operation in Solar Research. Vol. II. Manchester. 1908. 8vo. 244 pp. Cloth.

Minutes of the Meeting of the Board of Directors Held in the Hall of the California Club, 1750 Clay Street, San Francisco, March 27, 1909, at 7:30 p. m.

The following Directors were present: Burckhalter, Townley, Morse, Cushing, Hale, Galloway, and Crawford. President Burckhalter presided.

The report of the Nominating Committee was presented and accepted.

A written report was presented by the committee on location. After discussion it was moved and seconded that the President and Secretary be empowered to lease the room in the Phelan Building recommended by the committee, the rental being $20 per month. Carried.

The Secretary presented and read a letter from Dr. G. W. Hill accepting very gratefully the Bruce Medal for 1909.

The following were elected to membership:

Miss Florence Brown, 2702 Virginia Street, Berkeley, Cal.

Mr. H. C. Williams, 1476 Washington Street, San Francisco.

The following were elected institutional members:

Philadelphia Observatory—Broad and Green Streets, Philadelphia, Pennsylvania.

Smith College Library—Northampton, Massachusetts.

Washington University Library—St. Louis, Missouri.

Exchange with the *Gazette Astronomique* of the "Société d'Astronomié d'Anvers" was authorized.

The minutes of the last meeting of the Board were approved.

Adjourned.

Minutes of the Twenty-First Annual Meeting of the Astronomical Society of the Pacific, Held in the Hall of the California Club, 1750 Clay Street, San Francisco, March 27, 1909, at 8 p. m.

President Burckhalter presided.

The minutes of the last meeting of the Society were approved.

The report of the nominating committee was presented and printed ballots distributed, after which the polls were opened. The polls were closed at 9 p. m. and Messrs. McAdie and Baird were appointed tellers to canvass the returns.

The report of the auditing committee was presented by Chairman Ziel.

Moved and seconded that the report be received and all criticising matter be stricken out.

A motion to table the report temporarily was made, seconded and carried. After the address of the evening the previous question was put and carried.

Mr. ZIEL presented a further report concerning a certain adjustment in the funds. No action.

The annual report of the Treasurer was presented by Director GALLOWAY in the absence of Treasurer RICHARDSON. The report was accepted.

The following resolution was introduced:

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by the said Board during the past fiscal year, are here now, by this Society, approved and confirmed. Moved, seconded and carried.

The Secretary presented and read the letter of Dr. G. W. HILL accepting the Bruce Medal.

President BURCKHALTER formally presented the Bruce Medal for 1909 to Dr. G. W. HILL. As Dr. HILL could not be present to receive the medal, the President directed the Secretary to send it to him with expressions of good wishes and the high esteem in which the Society holds him.

President BURCKHALTER then introduced Dr. GEORGE ELLORY HALE, Director of the Mount Wilson Solar Observatory, who delivered a most interesting address upon "The Work of the Mount Wilson Solar Observatory." The lecture was profusely illustrated with stereopticon views.

Upon the conclusion of the address it was moved and seconded that a vote of thanks be given to Dr. HALE. The motion was carried by a rising vote.

The tellers reported that the following had received a majority of the votes cast for Directors: C. BURCKHALTER, W. W. CAMPBELL, G. E. HALE, F. MORSE, R. G. AITKEN, D. S. RICHARDSON, W. H. CROCKER. C. S. CUSHING, J. D. GALLOWAY, R. T. CRAWFORD, E. J. MOLERA. These eleven were then declared elected to be Directors for the ensuing year.

The tellers reported that the following had received a majority of the votes cast for Committee on Publication: S. D. TOWNLEY, J. D. MADDRILL, H. D. CURTIS. These three were then declared elected to be members of the Committee on Publication for the ensuing year.

Adjourned.

REPORT OF THE DONOHOE COMET-MEDAL COMMITTEE FOR THE YEAR 1908.

The following comets were discovered during the year 1908:—

Comet *a* 1908, an unexpected comet, was discovered (photographically) by Professor Dr. MAX WOLF, at Heidelberg, on January 2, 1908.

Comet *b* 1908, ENCKE'S comet, was observed on its return by Mr. R. WOODGATE, at the Cape of Good Hope, on May 27, 1908.

Comet *c* 1908, an unexpected comet, was discovered (photographically) by Professor D. W. MOREHOUSE, at the Yerkes Observatory, on September 1, 1908.

The Donohoe Comet-Medal of the Astronomical Society of the Pacific has been awarded to the discoverers of comets *a* and *c*.

The number of Donohoe Comet-Medals awarded to date is sixty-six.

Respectfully submitted,

March 27, 1909.

W. W. CAMPBELL,
C. D. PERRINE,
S. D. TOWNLEY,
Committee.

TREASURER'S REPORT.

GENERAL STATEMENT OF THE FUNDS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC ON MARCH 27TH, 1909.

In the William Alvord Fund	$ 5,008 56
Alexander Montgomery Library Fund	3,818 51
Donohoe Comet-Medal Fund	727 68
Bruce Medal Fund	2,652 94
Life Membership Fund	1,924 36
John Dolbeer Fund	5,000 00
General Fund	853 56
Total	$19,985 61

ASSETS.

Bonds on deposit in the Mercantile Trust Co	$14,418 02
Cash on deposit Humboldt Savings Bank	331 94
" " " Savings and Loan Society	437 06
" " " Security Savings Bank	659 49
" " " San Francisco Savings Union	727 68
" " " Mutual Savings Bank	663 22
" " " German Savings and Loan Society	924 36
" " " Union Trust Company	970 28
" " " Donohoe-Kelly Banking Company	853 56
Total	$19,985 61

TRANSACTIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 27, 1909.

WILLIAM ALVORD FUND.

DR.

Balance March 28, 1908—	
Bonds with Mercantile Trust Company	$ 4,239 56
Cash in Humboldt Savings Bank	331 94
Cash in Savings and Loan Society	437 06
Interest received on Bonds during year	200 00
On Humboldt Bank Deposit	13 53
On Savings and Loan Deposit	8 74
	$ 5,230 83

Cr.		
Interest on Bonds transferred to General Fund	$200 00	
On Humboldt Bank Deposit, General Fund	13 53	
On Savings and Loan Deposit, General Fund	8 74	
		$ 222 27
Balance March 27, 1909		$ 5,008 56

BRUCE MEDAL FUND.

Dr.		
Balance March 28, 1908—		
Bonds in Mercantile Trust Company		$ 1,989 72
Cash in Mutual Savings Bank		832 21
Interest received on Bonds during year		100 00
On Mutual Savings Bank Deposit		32 03
Refund by French Mint		64
		$ 2,954 60
Cr.		
By one gold medal from French Mint	$100 00	
Expressage and postage	5 00	
Transfer to Life Membership Fund	196 66	
		301 66
Balance March 27, 1909		$ 2,652 94

DONOHOE COMET MEDAL FUND.

Dr.	
Balance Cash March 28, 1908, in San Francisco Savings Union	$ 698 35
Interest on Deposit for year	29 33
Balance March 27, 1909	$ 727 68

ALEXANDER MONTGOMERY LIBRARY FUND.

Dr.	
Balance March 28, 1908—	
Bonds in Mercantile Trust Company	$ 3,159 02
Cash Security Savings Bank	549 42
Interest on bonds	150 00
Interest on deposit in Security Savings Bank	20 07
Cr.	$ 3,878 51
By allowance on account salary of Secretary	60 00
Balance March 27, 1909	$ 3,818 51

LIFE MEMBERSHIP FUND.

Dr.		
Balance March 28, 1908—		
Bonds in Mercantile Trust Company		$ 1,000 00
Cash in German Savings and Loan		727 70
Interest on bonds		40 00
Interest on deposit in German Savings and Loan		29 55
Transfer from Bruce Medal Fund		196 66
Cr.		$ 1,993 91
By Interest on bonds to General Fund	$ 40 00	
Interest on bank deposit to General Fund	29 55	
		69 55
Balance March 27, 1909		$ 1,924 36

JOHN DOLBEER FUND.

Dr.		
Balance March 28, 1908—		
Bonds in Mercantile Trust Company		$ 4,029 72
Cash in Union Trust Company		970 28
Interest on bonds		190 00
Interest on bank deposit		35 22
		$ 5,225 22
Cr.		
Interest on bonds to General Fund	$190 00	
Interest on bank deposit to General Fund	35 22	
		225 22
Balance March 27, 1909		$ 5,000 00

GENERAL FUND.

Dr.		
To Receipts as follows:		
Balance March 28, 1908		$ 619 10
From sale of *Publications*		72 34
Dues		858 27
Exchange of Edison Electric Bonds		192 23
Rhine and Moselle Company—Insurance		125 00
Cushing & Cushing—fees returned		12 50
Duplicate check returned		2 00
Alexander Montgomery Library Fund		60 00
William Alvord Fund—interests		222 27
John Dolbeer Fund—interests		225 22
Life Membership Fund—interests		69 55
Total		$ 2,458 48
Cr.		
By Expenditures as follows:		
C. A. Murdock and Company, Printing—including Publications 118 to 124, inclusive	$1,146 70	
Salary of Secretary	160 00	
Salary of Treasurer	60 00	
Printing, postage, expressage, etc., by Secretary	67 92	
Postages by other officials	14 95	
Carnegie Institute Hand Book	4 00	
Astronomical Journal	5 00	
University of Chicago	30 00	
Hall rent, meetings of March, 1908 and 1909	40 25	
Lantern service, March 28, 1908	12 00	
Miscellaneous printing	17 05	
Safe-deposit box	4 00	
Making seal for the Society	10 00	
Mercantile Trust Company, care of bonds	14 00	
Insurance of library	4 75	
Miscellaneous	14 30	
		1,604 92
Balance March 27, 1909		$ 853 56

Dues unpaid for 1909	$510 00
Dues unpaid for 1908	135 00
Dues unpaid for 1907	90 00
	$735 00

No unpaid bills on hand.

Funds of the Astronomical Society of the Pacific Held in Deposit by the Mercantile Trust Company of San Francisco, at 464 California Street.

These securities are all of the face denomination of $1,000, and the values given represent their original cost to the Society.

Life Membership Fund.	
One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937, interest payable in January and July	$ 1,000 00
Alexander Montgomery Library Fund.	
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932, interest payable in January and July	1,040 00
One Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bond, No. 641. Principal due October, 1929, interest April and October	1,084 02
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665. Principal due January, 1915, interest payable January and July	1,035 00
Bruce Medal Fund.	
One Bay Company's Power Company 1st consolidated mortgage 5 per cent Sinking Fund Gold Bond No. 1636. Principal due September, 1930, interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922, interest payable in March and September	977 22
John Dolbeer Fund.	
One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937, interest payable in January and July	1,000 00
One Oakland Transit Consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932, interest payable January and July	1,040 00
One Bay Counties Power Company's 1st consolidated mortgage 5 per cent Sinking Fund Gold Bond, No. 1637. Principal due September, 1930, interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837. Principal due September, 1922, interest payable March and September	977 22
William Alvord Fund.	
Two Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bonds, Nos. 656 and 657. Principal due October, 1929, interest payable in April and October	2,168 06
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915, interest payable in January and July	2,071 50
Total, 14 bonds; value	$14,418 02

D. S. Richardson, *Treasurer.*

Minutes of the Meeting of the Board of Directors, Held in the Hall of the California Club, 1750 Clay Street, San Francisco, March 27, 1909, at 10:15 P. M.

Present: Directors BURCKHALTER, HALE, MORSE, GALLOWAY, CUSHING, MOLERA, CRAWFORD.

Retiring President BURCKHALTER called the meeting to order.

Director W. W. CAMPBELL was elected to be President.

Director GEO. E. HALE was elected to be First Vice-President.

President CAMPBELL being absent, Vice-President HALE then took the chair. The election to the remaining offices resulted as follows:

Second Vice-President: F. MORSE.

Third Vice-President: E. J. MOLERA.

Secretary and Treasurer: D. S. RICHARDSON.

Secretary (Lick Observatory): R. G. AITKEN.

Comet Committee: CAMPBELL (ex-officio), TOWNLEY, CURTIS.

Library Committee: CRAWFORD (Chairman), TOWNLEY, EINARSSON.

Moved, seconded and carried, that the matter of arranging the transfer of the Society's property to the new room in the Phelan Building, and the furnishing of the room be left to the Chairmen of the Committees on Finance and Library.

Moved and seconded that the Library Fund be charged ten dollars per month for the rent of the new room, and that an amount equal to the insurance received from the Rhine and Moselle Insurance Co. now in the General Fund be applied to fitting up the room. Carried.

Moved and seconded that the salary of the Secretary-Treasurer be twenty dollars per month, of which five dollars is to be taken from the Library Fund.

The Committee on Publication recommended the adoption of the following resolutions:

Resolved, That hereafter the day of the month be omitted from the date of the *Publications.*

Carried provided that the change is not contrary to the postal regulations in regard to second-class matter.

Resolved, That the Chairman of the Committee on Publication be authorized to employ whatever clerical help may be necessary in getting out the *Publications,* the total expenditures for this purpose in any one year not to exceed the sum of forty dollars.

Carried.

Resolved, That the interest from the Life Membership Fund, the John Dolbeer Fund and the Wm. Alvord Fund for the year 1909 be turned into the General Fund to be applied toward the cost of printing the *Publications.*

Carried.

Resolved, That no award of the Bruce Medal be made for the year 1910.

Carried.

The Committee on Publication of the Astronomical Society of the Pacific, to which the matter of amendments to the By-Laws was referred, reported as follows:

1. The By-Laws of the Society, the statutes for the bestowal of the Bruce Medal and the rules relating to the comet medal, were last printed in 1897, as Number 57 of the Publications, volume 9, page 163.

2. Since 1897 the By-Laws have been amended three times, as follows: (a) Article VIII, January 31, 1903 (see vol. 15, p. 52); (b) article IX, March 28, 1903 (see vol. 15, p. 141); (c) article II, August 31, 1905 (see vol. 17, p. 169).

3. We recommend that the second paragraph of article IX of the By-Laws be amended to read as follows:

A meeting shall be held in the Library of the Lick Observatory at a suitable hour on the last Saturday of August; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock p. m. on the last Saturdays of January, March, June and November, but it shall be within the discretion of the President to designate other places of meeting, in San Francisco or vicinity, for the meetings of January, June and November, whenever, in his opinion, such change will be to the advantage of the Society.

4. We recommend that when the statutes for the bestowal of the Bruce Medal are reprinted, a foot note be added to the tenth line of Article V, to read as follows: In response to a request made by one of the nominating observatories, the Board of Directors of the Astronomical Society of the Pacific construes the provision in Article V of the Statutes, referring to "Astronomers worthy to receive the medal for the ensuing year," to cover services rendered during the lifetime of the nominee.

It was the unanimous opinion of the six Directors present that the By-Laws be amended as recommended by the Committee, and the Secretary was instructed to obtain, if possible, the written consent of at least three other Directors.

The printing of the footnote to article V of the Bruce Statutes was authorized.

Adjourned.

Addendum to Minutes of the Meeting of the Board of Directors of the Astronomical Society of the Pacific, Held in Room 601, Merchants' Exchange Building, San Francisco, November 28, 1908, at 2 o'clock p. m.

Now that the announcement of the eighth award of the Bruce Gold Medal has been made, this addendum to the minutes of the meeting of the Board of Directors held November 28, 1908, is published and made part of the complete minutes of said meeting.

The result of the ballot showed that ten votes were cast for Dr. G. W. Hill. As the Statutes for the Bestowal of the Bruce Medal

require at least six votes, and more than this number having been cast for Dr. G. W. HILL, the award was thereupon made to him. The following certification was signed by the Directors:—

This is to certify that a special meeting of the Board of Directors of the Astronomical Society of the Pacific was held this day for the purpose of awarding the Bruce Medal for the year 1909, and that, the provisions of the statutes for the bestowal having been complied with, the medal was awarded to

GEORGE WILLIAM HILL

for distinguished services to astronomy, by the consenting votes of ten Directors.

CHARLES BURCKHALTER, S. D. TOWNLEY, FREMONT MORSE, CHARLES S. CUSHING, D. S. RICHARDSON, R. T. CRAWFORD, J. D. GALLOWAY, GEO. E. HALE,* R. G. AITKEN,* W. W. CAMPBELL.*

SAN FRANCISCO, CAL., November 28, 1908.

* By proxy.

OFFICERS OF THE SOCIETY.

Mr. W. W. Campbell .... *President*
Mr. G. E. Hale .... *First Vice-President*
Mr. F. Morse .... *Second Vice-President*
Mr. E. J. Molera .... *Third Vice-President*
Mr. D. S. Richardson .... *Secretary and Treasurer*
Mr. R. G. Aitken (Mount Hamilton, Cal.) .... *Secretary*

Board of Directors—Messrs. Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Molera, Richardson.

Finance Committee—Messrs. Molera, Crocker, Cushing.

Committee on Publication—Messrs. Townley, Maddrill, Curtis.

Library Committee—Messrs. Crawford, Townley, Einarsson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Townley, Curtis.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XXI. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1909. No. 126

THE CLOSING OF A FAMOUS ASTRONOMICAL PROBLEM.[1]

By W. W. CAMPBELL.

There is perhaps no more striking illustration of the power of scientific method than that relating to the discovery of *Neptune* in 1846. The planet *Uranus,* until then the outermost known member of our solar system, refused to follow the path computed for it by mathematical astronomers. With the progress of time the discrepancies between its predicted and observed positions grew constantly larger until, in the early eighteen-forties, the discordance amounted to fully seventy-five seconds of arc. This is a small angle—not more than one twenty-fifth the angular diameter of our moon—yet a very large angle to refined astronomy, for a discrepancy of two seconds would have been detected with ease. The opinion gradually developed that *Uranus* was drawn from its natural course by the attractions of an undiscovered planet still farther from the Sun than itself. ADAMS in 1843 and LE VERRIER in 1845, independently, and each without knowledge of the other's plans, attacked the then extremely difficult problem of determining the approximate orbit, mass, and position of an undiscovered body whose attractions should produce the perturbations observed. Regrettable and avoidable delays occurred in searching for the planet after ADAMS's results were communicated to the astronomer royal, in October, 1845. LE VERRIER's results were communicated to the Berlin Observatory in September, 1846, with the request that a search

[1] Reprinted, by special permission, from *The Popular Science Monthly,* May, 1909.

be made. The disturbing planet, later named *Neptune,* was found on the first evening that it was looked for, less than one degree of arc from the position assigned by LE VERRIER. If an energetic search had been made in England the year before, the planet would have been discovered within two degrees of the position assigned by ADAMS.

The above résumé of this unsurpassed achievement of the human mind forms a natural prelude to the present article, as it was the immediate forerunner of another problem, famous for half a century, which has now been brought to a satisfactory conclusion.

The determination of the orbit of the planet *Mercury* gave great difficulty to its investigators, principally from two causes:—

1. Being the innermost known planet in our system, remaining always near the Sun, and usually lost to view in the Sun's glare, fairly accurate observations of its positions could be secured only when the planet was near its greatest angular distances from the Sun and on the rare occasions when the planet passed between us and the Sun's disk. Consequently, observations of the highest accuracy were few in number; and,

2. There were large discrepancies between *Mercury's* predicted and observed positions, certainly not due to the attractions of any known members of our solar system.

LE VERRIER, of Neptunian fame, undertook a systematic investigation of *Mercury's* orbit, making use of all available observations. His results were derived and published in 1859. His work established that there were peculiarities in the planet's orbital motion which could not be due to the attractions of known masses of matter. Chief among the peculiarities was a slow rotation of the orbit itself. It is best described as a forward motion of the orbit's perihelion amounting to thirty-eight seconds of arc per century.

LE VERRIER announced that the outstanding differences between prediction and observation could be produced and explained by the disturbing attractions of an undiscovered planet closer to the Sun than *Mercury* and revolving around the Sun in an orbit lying nearly in the plane of *Mercury's* orbit. The mass of (the quantity of matter in) the hypo-

thetical planet would depend upon its distance from *Mercury:* if half way between *Mercury* and the Sun, its mass would be two thirds that of *Mercury;* if further from *Mercury,* the necessary mass would be greater; if nearer, smaller. A group or "ring" of small planets, instead of one large planet, would serve equally well, provided the total mass of the planetoids were of the same order of magnitude. LE VERRIER did not say that such an undiscovered planet or ring of planetoids did exist, but simply that it would account for the observed anomalies. The accuracy of his computations, published in detail, could not be questioned. The recognition of his masterly skill, and the memory of his entirely similar discovery of *Neptune,* assisted in convincing astronomers quite generally that a planet or group of planets existed. The discovery of the disturbing mass became at once a noted problem.

A body traveling around the Sun in a circular orbit whose radius is only one half *Mercury's* average solar distance would never be more than 12° from the Sun as viewed by terrestrial observers. A search for it by ordinary methods would accordingly be fruitless. A body large enough to shine brilliantly on a dark-sky background would be hopelessly lost in the bright sky near the Sun. *Mercury* itself, though running out between 20° and 30° from the Sun every few weeks, is seldom seen by any save astronomers; and they know where to look for it in the twilight sky.

Two special methods of discovery were applicable: (1) To detect the planet projected upon the Sun's disk when its orbital motion carried it between us and the Sun; (2) to search for it when the sky background was darkened at the time of a total solar eclipse.

Needless to say, a crop of discoverers by the first method grew up without delay. The observer of greatest note was LESCARBAULT, a rural physician of France. Immediately following the publication of LE VERRIER'S conclusions, LESCARBAULT announced that he had observed the transit of an unknown planet across the Sun's disk several months earlier. LE VERRIER journeyed to LESCARBAULT'S home, investigated all the circumstances of the observation, weighed the evidence, and concluded that a real planet had been seen. In fact, so

convinced of its reality were many scientific men that the name *Vulcan* was given to it. Older and later reported observations of the same character, to the number of twenty, were collected by LE VERRIER, and those which seemed to be in harmony with each other were made the basis of an orbit. *Vulcan* was found to be about one third *Mercury's* distance from the Sun, revolving once around the Sun in between nineteen and twenty days. In some of the text-books on astronomy appearing in the sixties and seventies, *Vulcan* was assigned a place in the solar system as conspicuous and as secure as that of *Mercury* itself.

Now it is probable that every one of the twenty observations referred to was erroneous, though made in good faith. In essentially every case the observer was inexperienced, and used a telescope of insufficient power, or one unprovided with measuring apparatus suitable for determining whether or not the subject observed was in motion across the Sun's disk. Even the observation of LESCARBAULT was in doubt when it later transpired that a Brazilian observer of considerable professional experience was at the same hour studying the region of the Sun in question and saw only uniform normal solar surface. The situation was not without its humorous side. For example, a Mississippi Valley weather prophet who saw *Vulcan* crossing the Sun's disk, said it was about "as large as a new [*sic*] silver half dollar"! Many of the observations no doubt referred to small sunspots which, with small telescopes, would look round.

Vulcan was searched for by visual observers at the principal eclipses of the sixties, seventies, and eighties. Two noted astronomers at the eclipse of 1878, WATSON and SWIFT, believed that they saw two new planets near the Sun. However, the two seen by WATSON did not agree with those seen by SWIFT, and still other astronomers at the same eclipse saw no strange bodies in the same regions. As the assigned locations depended upon the hasty readings of graduated circles, in which one can so easily make errors, in the press and excitement of eclipse conditions, the astronomical world quickly, and no doubt correctly, concluded that the objects seen were well-known neighboring stars.

The perfecting of dry-plate photography gave renewed interest to the search for *Vulcan,* both when passing over the solar surface and at times of eclipse. Although the Sun has been photographed almost daily during the past twenty years, at one observatory or another, no experienced observer has seriously claimed that his plates recorded an unknown planet crossing the Sun. Neither were eclipse searches more successful: the well-known bright stars lying nearly in the direction of the Sun were photographed, but no strange bodies. Curiously enough, the optical principles governing the efficiency of cameras in this search were overlooked for many years, and faint objects near the Sun—say stars fainter than the fourth magnitude—were not observable, because their images, though formed on the photographic plates, were overwhelmed and buried from sight in the general darkening of the photograph by the bright-sky background. It was not until 1900 that the elements of the problem of photographing faint bodies near the Sun were comprehended. While preparing for the eclipse of that year, three astronomers, Professor W. H. PICKERING, of Harvard College Observatory, and Messrs. PERRINE and CAMPBELL, of the Lick Observatory, independently arrived at the same simple conclusion that the focal lengths of the intramercurial-search cameras should be relatively long, in order to reduce the intensity of the sky exposure on the plates without reducing the intensity of the star images, and thus let the latter be seen on the negative. The principles involved are so simple as hardly to call for elucidation.

Let the two cameras have lenses of equal aperture, say three inches, of equal transparency, and capable of covering equal *angular* fields of view, say a circle ten degrees in diameter. Let one be of short focus, twenty-one inches, and the other of long focus, 135 inches. The powers of the two lenses to record stellar points on the sensitive plates in focus, under good atmospheric conditions, are not very unequal, for the two lenses collect equal quantities of light and condense the light into images of very nearly the same size. Both collect the same quantity of sky light, but the longer-focus camera spreads it (more thinly) over an area $(135)^2/(21)^2 = 41$

times the greater. It is evident that faint-star images hopelessly lost to view on the sky-blackened small plate may be seen with ease on the nearly clear glass of the large plate. We may safely say that the large plate will show images of stars three or three and one half magnitudes fainter than the small plate. The same advantage exists for small intramercurial planets as for stars, provided the exposures do not exceed two or three minutes in length, as they seldom do at eclipses. In longer exposures on intramercurial planetoids the advantage would usually be lost, as their rapid (and unknown) motions would cause their images on the plate to move, slowly with short-focus and rapidly with long-focus cameras, thus drawing them out into trails. With the longer instrument here described, an eight-minute exposure would in general be no more effective than one of four minutes. The most successful instrument for the search in question must compromise between the advantage of long focus in reducing sky density, and the disadvantage of long focus in producing long trails. Shorter exposures, giving shorter trails, may be provided by increasing the diameter of the lens, but this in turn means greater unavoidable optical aberrations in the outer areas of the region photographed, which is a reduction in efficiency. In this as in all instruments, extensive experience and good judgment must combine to decide upon the best compromise-proportions.

Professor PICKERING, of Harvard, and Mr. ABBOT, of the Smithsonian Institution, used such cameras at the total solar eclipse of 1900. The latter observer was favored with good conditions, in North Carolina, and he secured one photograph of a considerable area surrounding the eclipsed Sun. Quite a number of the stars known to exist in this region were photographed; but in the absence of a duplicate photograph of the same region, he could not decide whether certain apparent images on the plate were due to unknown planets, or were defects such as always exist in photographic films.

At the eclipse of 1901, in Sumatra, Mr. ABBOT, of the Smithsonian Expedition, and Mr. PERRINE, in charge of the Crocker Expedition from the Lick Observatory, were prepared, with four cameras each, to secure duplicate photographs covering a large area extending east and west from the Sun. Conditions

were unfortunately against the success of Mr. ABBOT'S plans, but thin clouds at the time of the eclipse let twenty-five per cent of the light come through to Mr. PERRINE'S photographic plates. The area covered in duplicate was 6° x 38°, extending along the direction of the Sun's equator, with the Sun in the center of the region. The plates recorded 170 well-known stars; and all apparent images not of ordinary stars were proved by the duplicate plates to be defects in the films. In two thirds of the area stars down to the eighth magnitude and many fainter ones were recorded; and in one third the area, covered with thicker clouds, stars were recorded down to the fifth and sixth magnitudes.

At the eclipse of 1905 Mr. CROCKER made it possible for me to organize expeditions to Labrador, Spain, and Egypt, each equipped with four intramercurial cameras, in addition to apparatus for other lines of research. The details of the twelve cameras were planned by Dr. PERRINE, the instruments were constructed under his supervision, and any photographic plates obtained with them at the three stations were to be assigned to him to examine for possible intramercurial-planet images. The Labrador group of four cameras, mounted at the station by Dr. CURTIS, made no contribution because of the severe storm conditions prevailing at the time of totality. The Egyptian cameras, mounted by Professor HUSSEY, recorded a considerable number of stars, but the sky, though clear in the usual sense, was full of dust, and the Sun and the surrounding region covered by the search were at a low altitude. The Spanish cameras, photographing through clouds which permitted only twenty or thirty per cent of the light to pass, recorded fifty-five stars down to about the seventh and eighth magnitudes. All suspected images not occupying the positions of known stars were proved to be defects in the films.

The eclipse of 1908 in the South Seas was utilized by the Crocker Expedition to cover a region extending east and west along the Sun's equator with duplicate exposures. Notwithstanding interference from rain and clouds at the beginning of totality, clear sky prevailed during the last two thirds of the four critical minutes. Dr. PERRINE finds more than 500 images of well-known stars on the plates, and no images of unknown

bodies. Stars are recorded down to nearly the ninth visual magnitude.

It is not absolutely certain that intramercurial planets, revolving around the Sun in elliptical orbits would be seen in projection entirely within the area of 9° x 29° lying along the solar equator and equally east and west of the Sun's center, yet there are exceedingly strong reasons to believe such would be the case. The eight large planets and the 650 ± minor planets in our system revolve around the Sun in the same direction, and, excepting a small proportion of the asteroids, so nearly in the Sun's equatorial plane that the parts of their orbit planes lying within the limits for intramercurial planets would be projected upon the photographed area. The central plane of the zodiacal light differs little from the Sun's equatorial plane. It is certain, also, that any intramercurial planets originally moving in planes inclined at large angles to *Mercury's* orbit plane would gradually be compelled by the attractions of *Mercury* and the other major planets to move in planes inclined at small angles to the ecliptic. The coincidence of the satellite planes in the systems of *Jupiter* and *Saturn,* and no doubt of *Uranus* and *Neptune* also, with the equatorial planes of these planets is another analogy of some weight. Admitting, for completeness, the hypothesis of an extensive system of small planets moving in planes making a variety of angles with the ecliptic and Sun's equator, some would certainly have been caught in the region photographed. A single planet, or a half dozen planets, massive enough to meet the requirements, moving in *any* orbit planes would no doubt have been discovered a generation ago. In view of these facts, there is little reason to fear that any planets effective in disturbing *Mercury's* motions were north or south of the regions covered by photography.

Inasmuch as planets, shining by reflected light, do not act upon photographic plates so strongly as stars of the same visual magnitude, we may say that exposures which recorded stars down to the ninth magnitude should have recorded planets down to the eighth. From the known brightness, distance from the Sun, and approximate diameter of a few of the asteroids revolving in space between *Mars's* and *Jupiter's*

orbits, Dr. PERRINE has computed that an average eighth-magnitude intramercurial planet could scarcely be larger than thirty miles in diameter and that roughly a million such bodies, of great density, would be required to supply the disturbing effect observed in *Mercury's* orbit.

Taking all these points into consideration, I think we may say that the investigations by PERRINE, forming a part of the work of the Crocker Eclipse Expeditions from Lick Observatory, have brought the observational side of the Intramercurial Problem, famous for a half century, definitely to a close. It is not contended that no such planets will be discovered in the future; in fact, it would not be surprising, nor in opposition to the opinions here expressed, if several such bodies should be found; but it is confidently believed that any such bodies would fail hopelessly to supply the great mass of material demanded by LE VERRIER's theory, as PERRINE pointed out in discussing the Sumatra observations of 1901.

On the occasion of a future eclipse of fairly long duration, occurring in the dry season, it might be well to repeat the observations, inasmuch as the instruments are in approximate readiness, and the observations at the three past eclipses were made through thin clouds twice, and with cloud-shortened exposures the third time. The cameras are capable of recording tenth-magnitude stars with three-minute exposures in clear sky. It will not be advisable to use these instruments at the eclipses of the next four years.

There are other chapters, on the theoretical side of the problem, to be entered here.

Professor NEWCOMB's researches on planetary motions extended much further than LE VERRIER's. He found small terms in the motions of *all* the inner planets—*Mercury, Venus,* Earth, *Mars*—which are not due to the disturbing attractions of any known masses of matter. The chief discrepancies, aside from the large one found in *Mercury's* motion by LE VERRIER and confirmed by NEWCOMB,[1] are in the perihelion of *Mars,* and in the nodes of *Mercury* and *Venus.* These outstanding residuals will be tabulated on a later page.

[1] LE VERRIER's discrepancy amounted to 38″, NEWCOMB's to 41″.

The attractions of any one planet or ring of small planets, sufficient to account for the excess motion of *Mercury's* perihelion, failed to account for the other discrepancies discovered by NEWCOMB for the four planets. Satisfactory causes were looked for in a possible ellipsoidal form of the Sun, in a hypothetical ring of small planets between *Mercury* and *Venus,* in an assumed minute variation in the law of gravitation from the Newtonian inverse square of distances, and in other assumptions, but in vain. One hypothesis, that the finely divided material which gives rise to the zodiacal light (by reflecting the Sun's rays) is the responsible disturbing mass, has been discussed several times since the days of LE VERRIER and as many times rejected, with one exception.

The exception is Professor SEELIGER's recently published investigation. With great skill and with entirely reasonable assumptions as to the form of space occupied by the zodiacal material, and as to the density of the distribution of the material in this space, he establishes that there is sufficient mass to account for the discrepancies in the motions of all the four planets.

The following table exhibits the results of SEELIGER's theory in the first column of figures, and the actual results of observation as determined by NEWCOMB in the second column. The quantities in the third column, which bear the sign $\pm$, are the "probable errors" assigned by NEWCOMB to his results; and, for the benefit of non-mathematical readers, we may explain that these "probable errors," deduced from the observations themselves, are indications of the uncertainties existing in the quantities to which they are attached. In this table e and i are respectively the eccentricity of the orbit and the inclination of the orbit plane to the ecliptic; and $\Delta\Pi$, $\Delta\Omega$, and Δi are respectively the changes, per century, in the longitude of perihelion, in the longitude of node, and in the inclination of the orbit plane, unaccounted for by the attractions of known masses, as in the second column, and produced by the attractions of the zodiacal matter as computed by SEELIGER. In the last column are the differences between the SEELIGER and NEWCOMB numbers: in other words, a comparison of theory with actuality. These differences are small. All are within the probable errors

in the third column; with one exception, far within these probable errors.

		Seeliger.	Newcomb.		N.-S.
$e \cdot \Delta\Pi$	*Mercury*	$+8''.49$	$+8''.48$	$\pm 0''.43$	$-0''.01$
	Venus	$+0\ .05$	$-0\ .05$	$\pm 0\ .25$	$-0\ .10$
	Earth	$+0\ .07$	$+0\ .10$	$\pm 0\ .13$	$+0\ .03$
	Mars	$+0\ .59$	$+0\ .75$	$\pm 0\ .35$	$+0\ .16$
$\sin i \cdot \Delta\Omega$	*Mercury*	$+0\ .65$	$+0\ .61$	$\pm 0\ .52$	$-0\ .04$
	Venus	$+0\ .58$	$+0\ .60$	$\pm 0\ .17$	$+0\ .02$
	Mars	$+0\ .23$	$+0\ .03$	$\pm 0\ .22$	$-0\ .20$
Δi	*Mercury*	$+0\ .52$	$+0\ .38$	$\pm 0\ .80$	$-0\ .14$
	Venus	$+0\ .17$	$+0\ .38$	$\pm 0\ .33$	$+0\ .21$
	Mars	$-0\ .02$	$-0\ .01$	$\pm 0\ .20$	$+0\ .01$

We cannot ascribe this remarkable agreement between NEWCOMB'S and SEELIGER'S results to fortunate chance, and it is scarcely possible to doubt that in the zodiacal-light materials lie the causes of the discrepancies referred to. I have little hesitation in venturing the opinion that SEELIGER'S investigation marks an epoch in the application of NEWTON'S law of gravitation to the motions within the solar system. At one stroke he appears to have removed a group of discrepancies which served as bases for many inquiries as to the preciseness and sufficiency of the Great Law. With all respect to SEELIGER'S genius and labor, however, scientific caution will value confirmation of his results by other investigators.

SEELIGER'S assumptions as to the distribution and mass of the zodiacal material are of interest, especially when we recall that the zodiacal light within some twenty degrees of the Sun is unobservable, on account of the glare, and that the brightness of the light is a poor index to the mass: a given quantity of matter, finely divided, would reflect sunlight more strongly than the same quantity existing in larger particles. For the mathematical development of the subject he assumed that the material is distributed throughout a space represented by a much-flattened ellipsoid of revolution whose center is at the Sun's center, whose axis of revolution coincides more or less closely with the Sun's axis, whose polar surfaces extend twenty or thirty degrees north and south of the Sun (as viewed from the Earth), whose equatorial regions extend con-

siderably beyond the Earth's orbit, and in which the density-distribution of materials decreases as a function both of the linear distance out from the sun and of the angular distance out from the equatorial plane of symmetry. According to these assumptions, surfaces of equal densities are concentric ellipsoidal surfaces, and the number of such ellipsoids can be increased or decreased according as the computer may desire to represent more or less closely any assumed law of density-variation within the one great spheroid. Practically, SEELIGER found that the disturbing effects on the planets are almost independent of the law of distribution of the material, as related to distance from the Sun, as far out as two thirds of the distance to *Mercury*. He made use of only two ellipsoids: One with equatorial radius 0.24 unit[1] and polar radius 0.024, of uniform density; and the other with corresponding radii 1.20 and 0.24 of uniform but much smaller density. The total mean densities determined for his volumes, on the basis of unity as the mean density of the Sun, are, respectively, 2.18×10^{-11} and 3.1×10^{-15}; and the resulting combined mass of the two ellipsoids is 3.1×10^{-7} of the Sun's mass, which is roughly twice the mass of *Mercury*. The corresponding density of mass-distribution is surprisingly low. In the inner and denser ellipsoid, the matter, if as dense as water, would occupy 1 part in 30,000,000,000 of the space; if as dense as the Earth, only 1 part in 160,000,000,000.

The reader should be cautioned against obtaining the impression that SEELIGER's two ellipsoids represent the truth as to the law of distribution of density, for such is not the case. A very large number of ellipsoids, doubtless decreasing rapidly in density as one proceeds from the Sun outward, would be required to represent the actual law. SEELIGER found that the attractive effect of the mass inside of the ellipsoid with maximum radius 0.24 was essentially independent of the law of distribution; and for convenience in the computations he therefore assumed the density in the said ellipsoid to be uniform. A solution based upon a greater number of constitutent ellipsoids would perhaps be a slight improvement.

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[1] The distance from the Sun to the Earth being 1.00.

The logic of SEELIGER's work rests finally upon the reasonableness of his assumptions and deductions concerning the distribution and density of the zodiacal-light materials; and these are not out of harmony with the meager knowledge of the zodiacal light which we have obtained by direct observation.

In consequence of SEELIGER's results further direct observations of the zodiacal light take on renewed interest.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1909.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon	July 3,	4^h 17^m	A.M.	Full Moon	Aug. 1,	1^h 14^m	P.M.
Last Quarter	" 9,	10 58	P.M.	Last Quarter	" 8,	4 10	A.M.
New Moon	" 17,	2 45	A.M.	New Moon	" 15,	3 55	P.M.
First Quarter	" 25,	3 45	A.M.	First Quarter	" 23,	7 55	P.M.
				Full Moon	" 30,	9 8	P.M.

The Earth passes aphelion, its greatest distance from the Sun, July 3d, 7 P.M., Pacific time.

Mercury is a morning star until August 4th, when it passes superior conjunction with the Sun and becomes an evening star, remaining such until October 12th. It reaches greatest west elongation on July 7th, being on that date 21° 12′ west of the Sun. During the first half of July it rises from an hour to an hour and a quarter before sunrise, and may be seen in the morning twilight under good weather conditions, but shortly after the middle of the month it draws too near the Sun for easy observation. After becoming an evening star, in early August, it moves away from the Sun, so that by the end of the month it is well out toward greatest east elongation, but even then it sets less than one hour after sunset, and it will hardly be in reach of naked-eye observation.

Venus is an evening star, setting a little more than an hour after sunset throughout the two months' period. The interval increases only ten minutes from 1^h 10^m on July 1st to 1^h 20^m on August 31st. The apparent distance between Sun and

planet increases about 12°, and this would mean an increase of about forty-eight minutes in the interval between the setting of the two bodies, but for the fact that *Venus* is moving southward much faster than the Sun, and this relative southward motion of the planet nearly counterbalances the gain due to increased distance. *Venus* and *Jupiter* are in very close conjunction on the night of August 11th-12th. The nearest approach is 12′, less than half of the apparent diameter of the Moon. This occurs about 11 P.M., Pacific time, some hours after the planets have set for all points in the United States; but the planets will be very close together on the evening of that date.

Mars is gradually drawing near opposition. It rises shortly before $11^h\ 30^m$ on July 1st, and at a little after 8^h P.M. on August 31st. It moves eastward and northward about 15° among the stars with gradually diminishing speed, until August 23d; it then begins its retrograde, westward, motion but moves only about half a degree before the end of the month. It is in the constellation *Pisces* and passes the vernal equinox on the afternoon of July 15th. It does not cross the celestial equator at that time, as it is then in the southern part of its orbit, and is about 5° south of the ecliptic. *Mars* passes perihelion on August 13th, more than a month before opposition. Its distance from the Sun diminishes from 64,000,000 miles to about 38,000,000, and it will be nearly three times as bright on August 31st as it was on July 1st. In fact, it will be within about ten per cent of its maximum brightness at the end of August, and will be very conspicuous.

Jupiter is in the western sky in the evening and forms with *Venus* the most prominent feature of that part of the heavens. On July 1st it sets at about $10^h\ 40^m$ P.M. and on August 31st it sets at a little after 7^h P.M., only a little more than half an hour after sunset. During the last week in August it will be almost too near the Sun for naked-eye observation, but its great brightness may make it possible to follow it to the end of the month. During July and August it moves 11° eastward and 5° southward, from the constellation *Leo* into *Virgo*. Its close conjunction with *Venus* on August 11th has already been noted. On the night of August 24th-25th it is in conjunction

with *Mercury,* the nearest approach being 40′, *Jupiter* south of *Mercury;* but both planets are then very close to the Sun, probably too close for *Mercury* to be seen, and *Jupiter* will not be an easy object.

Saturn rises half an hour after midnight on July 1st and at about 8^h 30^m P.M. on August 31st. It is in the eastern part of the constellation *Pisces* and moves about 1° eastward until August 6th, and then begins its westward or retrograde motion. By the end of August it will have moved about half a degree. As seen in the telescope, the rings will have widened out so that the minor axis is a little less than one fourth of the major.

Uranus comes to opposition with the Sun on the evening of July 11th and is then above the horizon the entire night. By the end of August it will set shortly after 1^h A.M. It moves about 2° westward during the two months, in the eastern part of *Sagittarius,* several degrees north and east of the bowl of the "milk-dipper." No bright star is near it, and in consequence it is not easily identified by naked-eye observations.

Neptune is in conjunction with the Sun on July 9th.

ANNOUNCEMENT.

Since the great fire of April, 1906, the Astronomical Society of the Pacific has had no permanent home. With the exception of a few books which were out at the time, its entire library and other belongings were destroyed. Through the courtesy of the authorities of the University of California temporary accommodations for the beginnings of the new library were provided in the Students' Observatory at Berkeley.

The Board of Directors of the Society begs to announce that new quarters have now been obtained in San Francisco and all books, pamphlets, magazines, and other matter intended for the Society should be sent to the new address, which is Room 748 Phelan Building, San Francisco, California.

The Secretary-Treasurer, Mr. D. S. Richardson, has established daily office hours, and all mail intended for him should be sent to the address given above.

NOTES FROM PACIFIC COAST OBSERVATORIES.

The Orbits of the *Cepheid* Variables Y *Sagittarii* and RT *Aurigæ;* with a Discussion of the Possible Causes of this Type of Stellar Variation.[1]

Of the several classes into which variable stars have been divided, only two—the Algol stars and the *Cepheid-Geminid* stars—have been shown to be distinguished by variable radial velocity. Of the nature and cause of variation in the Algol stars there can be no reasonable doubt, since all their observed phenomena point to the occurrence of stellar eclipses. The case of the *Cepheids* and *Geminids*,[2] however—I wish to treat the two classes as one—is by no means clear; and, since a number of these stars are bright enough for spectrographic work and as all so far investigated have been found to possess an orbital motion, there seems to be in this, one of the most vulnerable points for attacking the problem of stellar variability.

In order to give weight to any hypothesis regarding the cause of continuous variation, we must have a knowledge of the orbits of as many stars as possible; and to this end Director Campbell has suggested several stars of this type as subjects for special work by individual observers with the great refractor. Such a piece of work is described in the present paper.

Y *Sagittarii*.

The variability of brightness of Y *Sagittarii* was discovered by Sawyer in 1886. Since then its brightness has been ob-

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[1] Abstract from dissertation, published in full in *Lick Observatory Bulletin*, 151, 5, 82, 1909.

[2] These names, derived from those of the type-stars δ *Cephei* and ζ *Geminorum*, seem to have originated with Miss Clerke. The light of both classes varies continuously, but the light-curves of the *Cepheids* are steepest on the rise from minimum to maximum, while in the *Geminids* a minimum occurs midway between two maxima.

served by SAWYER, CHANDLER, YENDELL, LUIZET, and PICKERING, so that the nature and period of its variation have been established with considerable accuracy. The star's binary character was announced by CURTISS[3] in 1904.

The position for 1900.0 is $\alpha = 18^h\ 15^m.5$, $\delta = -18°\ 54'$; the light variation, according to CHANDLER, is from 6.6 magnitude to 5.8 magnitude; according to PICKERING, from 6.2 magnitude to 5.4 magnitude. The class is *Cepheid* and the spectral type approximately solar. From the observations of CHANDLER and PICKERING, covering an interval of about twelve years, the period of variation was determined as $5^d.77336$.

The spectrograms on which my orbital elements depend were obtained with the 36-inch refractor and the single-prism spectrograph ordinarily used at this observatory for stars too faint for the three-prism instrument. The comparison spectrum was furnished by the iron spark, using self-induction to eliminate the air lines. Two different kinds of plates were used—Seed's "27" and Lumière's "Sigma." The former have somewhat the finer grain, but the latter are considerably the faster. I obtained thirty-three plates in all, but owing to underexposure six of these were unfit for use.

These spectrograms exhibit the peculiarity noted by ALBRECHT[4] in the spectra of other stars of this class, the maximum intensity of the continuous spectrum being shifted toward the violet as the star's light approached a maximum and back toward the red as it approached a minimum.

The plates were measured with a Hartmann spectrocomparator.[5] As the instrument had not been used before, it was first necessary to investigate the errors of the screw. This was done in the manner described by HARTMANN[6] and the screw found to be very good, though there is indication of a slight periodic error. This error was, however, eliminated in measuring the plates by turning the screw through a half revolution between the direct and reverse measures. As a funda-

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[3] *Lick Observatory Bulletin*, **3**, 31, 1904; and *Astrophysical Journal*, **22**, 274, 1905.

[4] *Lick Observatory Bulletin*, **4**, 131, 1907.

[5] See article by Dr. J. H. MOORE, *Publications A. S. P.*, **19**, 24, 1907.

[6] *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, **18**, I.

mental plate I used a spectrogram of the sky, photographed on a Seed "27" plate, 1908, June 29th.

From the twenty-seven plates measured, the following elements were derived by the method of LEHMANN-FILHÉS:—

ORBITAL ELEMENTS OF Y *SAGITTARII.*

Period	$U = 5^d.77336$
Mean daily motion	$\mu = 62^\circ.3554$
Time of periastron passage	$T = 4^d.46$ after light-max.
Distance of periastron from node	$\omega = 32^\circ\ 00'$
Eccentricity	$e = 0.16$
Velocity of system	$V = +4.0^{km}$
Maximum radial velocity	$= +25.2^{km}$
Minimum radial velocity	$= -12.4^{km}$
Single amplitude of curve	$K = 19.0^{km}$
Projection of semi-major axis	$a \sin i = 1{,}485{,}000^{km}$

Within the errors of observation, there is no evidence of any irregularities in the velocity-curve, such as appear so strikingly in the curves of ζ *Geminorum*[7] and W *Sagittarii.*[8] It is noteworthy that the time interval between maximum light and maximum velocity of approach is unusually long for a variable of this class.

RT *AURIGÆ.*

The light-variability of RT *Aurigæ,* a star formerly known by FLAMSTEED's designation of 48 *Aurigæ,* was discovered by Mr. T. H. ASTBURY in March, 1905.[9] Two light-curves have been published, a preliminary one by WILLIAMS[10] and a more nearly definitive one by ASTBURY.[11]

From the discoverer's papers in the *Journal of the British Astronomical Association* are derived the following data:—

> α 1900, $6^h\ 22^m.1$; δ 1900.0, $+30^\circ\ 34'$; max., $4^m.93$; min., $5^m.91$; time from max. to min., $2^d.51$; period, $3^d.7282$; epoch of max., J. D. 2417173.36; class, *Cepheid.*

The spectral type is very approximately solar.

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[7] CAMPBELL, *Astrophysical Journal,* **13,** 90, 1901.

[8] CURTISS, *Astrophysical Journal,* **22,** 274, 1905; and *Lick Observatory Bulletin,* **3,** 36, 1904.

[9] *Journal of the British Astronomical Association,* **15,** 244, 1905.

[10] *Journal of the British Astronomical Association,* **15,** 270, 1905.

[11] *Journal of the British Astronomical Association,* **18,** 85, 1907; and **18,** 132, 1907.

The density of three preliminary plates of this star obtained with the single-prism spectrograph early in August indicated that it was bright enough for investigation with the three-prism instrument, and work with the latter was accordingly begun in September. On account of the star's faintness it was necessary to use Lumière's very rapid but coarse-grained "Sigma" plates and to open the slit much wider than is customary in using this spectrograph. Under these conditions the exposures varied from about one and three-fourths to three and one-half hours, depending upon the state of the air and the light phase of the star.

For the measurement of the plates I used the spectrocomparator and, as fundamental plate, a spectrogram of the sky was made on a Seed "27" plate, 1908, September 28th. The greater number of settings on each plate combined with the greater dispersion of the spectrograph to make the accuracy of the velocities derived from plates of this star much greater than that of the velocities determined for Y *Sagittarii*.

Twenty-six measurable plates were obtained, but in determining the velocity curve only twenty-two were used, though two of the remaining four give reasonably small residuals. Three of the unused four are much underexposed and the fourth was discarded because of its large residual, since three other plates in the same part of the curve give small residuals.

The orbital elements derived from the velocity-curve by the method of LEHMANN-FILHÉS are:—

PRELIMINARY ELEMENTS OF RT *AURIGÆ*.

Period	$U = 3^d.7282$
Mean daily motion	$\mu = 96°.5615$
Time of periastron passage	$T = 3^d.40$ after light-max.
Distance of periastron from node	$\omega = 92° \ 2'$
Eccentricity	$e = 0.36$
Velocity of system	$V = +21.50^{km}$
Maximum radial velocity	$= +38.54^{km}$
Minimum radial velocity	$= +4.02^{km}$
Single amplitude of curve	$K = 17.26^{km}$
Projection of semi-axis major	$a \sin i = 825{,}500^{km}$

Since publishing my original article, I have made a least-squares solution for the orbit of this star, obtaining the following final elements:—

FINAL ELEMENTS OF RT *AURIGÆ*.

Time from light-max. to periastron	$T = 3^d.423 \pm 0^d.020$
Distance of periastron from node	$\omega = 95°.016 \pm 2° 502$
Eccentricity	$e = 0.368 \pm 0.014$
Velocity of system	$V = + 21^{km}.434 \pm 0.399$
Maximum radial velocity	$= + 38^{km}.819$
Minimum radial velocity	$= + \ 2^{km}.895$
Single amplitude of curve	$K = 17^{km}.962 \pm 0^{km}.246$
Projection of semi-axis major	$a \sin i = 856{,}500^{km}$

By the least-squares solution the sum of the squares of the residuals was reduced from 28.69 to 22.05. The outstanding residuals are so grouped as to suggest that the orbit is not truly elliptic.

THEORIES CONCERNING THE CAUSE OF LIGHT CHANGE IN *CEPHEID* AND *GEMINID* VARIABLES.

Twelve stars whose light variation is continuous and of short period have now been investigated spectrographically with a considerable degree of completeness. We shall consider the various explanations that have been suggested as to the cause of their variability and test these explanations, as far as possible, by means of the observed facts.

The principal characteristics of stars of this type are:—

1. Their light varies without pause.
2. The amount of their light variation is usually about one magnitude.
3. Their periods are short—a few days only.
4. They are of a spectral type approximately solar; no Orion, Sirian, or Antarian stars having been found among them.
5. They seem to be found in greater numbers in certain parts of the sky, notably in the Milky Way,[13] but exhibit no tendency to form close clusters.
6. All those stars whose radial velocities have been studied have been found to be binaries, whose period of orbital revolution coincides with that of their light change.
7. The orbits, so far as determined, are all small, $a \sin i$ being $2{,}000{,}000^{km}$ or less.

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[13] Miss CLERKE, *System of the Stars*, 144, 1890.

8. Their maximum light synchronizes very closely with their maximum velocity of approach, and minimum light with maximum velocity of recession.[14]
9. No case has been found in which the spectrum of more than one component has been bright enough to be recorded in the spectrograms.

The first-mentioned characteristic sharply separates these stars from stars of the Algol type, whose light-curves always contain horizontal straight lines; and the eighth shows that their variation cannot be due to occultation by the dark companion, since in that case minimum must occur at inferior conjunction. The third property makes it imperative that a theory, to be successful, should connect the light variation with the orbital revolution.

In his discussion of the orbit of ζ *Geminorum,*[15] Dr. CAMPBELL suggested tidal disturbances[16] in an atmosphere surrounding the brighter component, due to the gravitational attraction of the darker; and explained the fact that minimum light occurs soon after periastron passage by supposing a reduction of brightness due to a sudden expansion of the gases of the atmosphere under the influence of maximum tidal action when near periastron. That maximum light, instead of minimum, occurs soon after the nearest approach of the two components in the cases of η *Aquilæ* and δ *Cephei,* he thought might be explained by the greater difference of tidal action in different parts of the orbits of these stars, owing to their greater eccentricity.

At that time, however, the orbits of only three stars of this class had been determined, and in the light of subsequent research on other variables of this type, there are serious objections to the general application of this theory.

First, no general relation seems to hold between the time of periastron passage and the time of greatest brilliancy.

Second, the theory in no way explains ALBRECHT's discovery of the time relation between maximum light and maximum velocity of approach.

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[14] ALBRECHT, *Lick Observatory Bulletin,* **4**, 138, 1907.

[15] *Astrophysical Journal,* **13**, 90, 1901.

[16] The tidal theory appears to have been first suggested by ROBERTS, of South Africa, *Astrophysical Journal,* **2**, 283, 1895.

Third, no increase in the range of brightness variation is found in the case of stars having orbits of greater eccentricity.

Moreover, if the tidal disturbance takes place in the bright star's atmosphere, we should expect to find bright lines in the spectrum, and this has never been observed. If, on the contrary, the disturbance occurs in the denser part of the body, it seems unlikely that the star should lose perceptibly in brilliancy during the few days that elapse before it is again subjected to maximum tidal action.

However, despite these obstacles to making tidal action a chief basis for explaining the light variations of these objects, it is very probable that this action does have a profound influence on the behavior of the system.

A second hypothesis for explaining the variation of stars of this type is that of a resisting medium in which the binary system is supposed to be enveloped, and the impact of whose particles causes the star's advancing side to become heated. This idea was first published by Dr. R. H. CURTISS[17] and has been somewhat elaborated upon by Professor F. H. LOUD.[18] The impact of the particles of a resisting medium of nebulous or meteoric matter might cause variation in a star's light in two ways—first, as the star revolved in its orbit, if it moved at different times with different speed or through portions of the medium having different densities, there would result a difference in the actual rate of emission of light; second, if the star moved like the Moon, keeping always the same face towards its dark companion, the preceding face would, by the impact of particles, be kept constantly hotter than the following side, and, as the star rotated, first the darker and then the brighter side would be presented to the observer.

The hypothesis of a resisting medium has many things in its favor, but chiefly the fact that it accounts for the synchronism of maximum light and minimum positive velocity.

That the variation of the star's light can be accounted for by a change in the rate of light emission is rendered improbable by the following facts:—

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[17] *Lick Observatory Bulletin*, **3**, 40, 1904; and *Astrophysical Journal*, **20**, 186, 1904.

[18] *Astrophysical Journal*, **26**, 369, 1907.

1. In order that the actual emission of light may vary, the star must cool perceptibly during the few days which elapse between successive passages through those parts of the orbit where the bombardment is most fierce. This would necessitate that the disturbance take place only in the outer and rarer parts of the star's atmosphere—a fact which is contradicted by the character of the spectrum.
2. No greater range of light variation is observed in stars having highly eccentric orbits than in those whose orbits are only slightly eccentric, and in general, there is no marked outburst of light when the star is near periastron.

If we make use of the hypothesis of a resisting medium, we must therefore restrict it to the case where the period of rotation of the bright star is equal, or nearly equal, to that of its revolution. Professor LOUD's ideas may, I think, be briefly summed up as follows: Since the star's binary character is betrayed, not by a doubling of the lines but by their periodic shift, one component only is luminous; its light is due to the bombardment of its surface by particles of the medium through which it moves, and to which its companion, since it is non-luminous, must be relatively at rest. The distance between the two components is so small that tidal action tends strongly to equalize the periods of rotation and revolution of the bright satellite; but, owing to the resistance imposed upon its motion, the satellite moves upon an ever-diminishing spiral, its period of revolution shortens, and therefore that period is always a little shorter than the period of rotation. The effect of this lag of the rotation is to cause the heated area on the satellite, produced by meteoric bombardment, to become unsymmetrical, the point of greatest heat moving slowly along the equator into colder regions, leaving behind it a slowly cooling band. To an observer, then, whose line of sight is not perpendicular to the plane of the orbit, the star's light would vary continuously, but the time-interval from minimum to maximum would be shorter than that from maximum to minimum—a well-known distinguishing feature of the light-curves of many vari-

ables of this type. Those cases where the asymmetry in the light-curve is reversed or where, as in ζ *Geminorum*, it does not exist, he explains by assuming that the rate of rotation is more rapid than, or equal to, that of revolution. Irregularities in the light-curves are explained by the separate or joint action of three causes: Ellipticity of the orbit, producing greater speed near periastron; "libration," or the optical effect of variation of angular speed in revolution owing to the orbit's eccentricity, while the rotation rate is constant; and variations in the density of the medium.

In the majority of the variables of this class whose orbits are known, the light maximum occurs a little before maximum velocity of approach—instead of a little after or exactly simultaneous with it, as we should expect on this hypothesis. This Loud explains by supposing that the meteoric bombardment induces in some cases not only an increase of light but an increase of absorption, so that we do not at once get the full effect of the maximum light—a supposition whose truth we cannot disprove, though it seems to have little to sustain it.

Whatever the manner in which the impact of meteoric particles may produce the variation of light, it is certain that the work done by the star in imparting momentum to the meteors must tend to shorten the period of revolution; and perhaps a crucial test of the hypothesis may be found in the calculation of the relations between this shortening and the quantity of energy emitted in the forms of light and radiant heat.

In my original article I accordingly calculated these relations and found that, for a star moving in a circular orbit with a period of six days and a speed of 20^{km} per second, through a flock of meteors sufficiently dense to produce by their bombardment a variation in the star's light of 0.8 magnitude, the shortening of the star's period would be seventeen seconds per year. Only one star of this type has been observed to possess a secularly diminishing period. This star is δ *Cephei*, whose period, according to Chandler, shortens by only $0^s.108$ per year, the period itself being between five and six days, and the variation in brightness 0.9 magnitude.

It is true that, between stars situated so close together as are the *Cepheid* variables, tidal action might be very strong

and that by its tendency to lengthen the period it might counteract the tendency of the resisting medium to shorten it. It would seem strange, however, that in so many cases the two effects should so exactly balance that no change in either direction could be detected. Besides, there are many binaries —chiefly variables of the Algol type—whose periods are as short and whose components are as closely situated as are those of the *Cepheids,* but in whose periods no secular change has been detected. In fact, the only Algol variable in whose period CHANDLER notes any secular change is, as we have seen, *U Coronæ,* whose period is shortening but which gives no evidence of light variations of the δ *Cephei* or continuous type. It seems possible, indeed, that among the *Cepheid* stars tidal action has arrived at the stage where both bodies are drawn into prolate ellipsoids and each keeps always the same face towards the other, so that the period has no longer any tendency to increase.

Aside from the change of a star's period, there are other considerations which militate against the hypothesis of bombardment as an explanation of continuous light variation. For example, since these stars move at fairly high speed in small orbits, the invisible companion must be a body of considerable mass as compared with the star that we see. Why, then, if the impact of meteoric bodies is sufficient to produce a large percentage of the radiation of one component, does it not make the other also visible? The meteoric bodies cannot remain at rest relative to either of the components, so we must suppose those particles which the bright star picks up to be moving in orbits about the dark component. If these orbits have the same eccentricity as that of the bright star and if the bodies are moving in the same direction as the star, they must move with nearly the same speed and we can have no violent collisions; if they cross the star's orbit at a large angle, then the star's brightest point will not be in front, but at the side; and if they move in retrograde orbits nearly coincident with the orbit of the star, the star should, in a comparatively few revolutions, collect all the meteors near its path, so that all bombardment would cease.

The question now arises whether, in the present state of our knowledge, a more satisfactory hypothesis for explaining the phenomena of these stars can be found. We have seen that it is unlikely that the variation in brightness can be due to an actual change in the rate of light emission, since in that case the character of the spectrum should change radically during the interval between maximum and minimum. It is clear also that the variation cannot be produced by rotation combined with the greater heating of the star's advancing side by the impact of meteoric particles. Since, however, the character of the spectrum indicates the presence of an absorbing envelope about the luminous body of the star, the change in brilliancy may be due to a variation of absorption; and it is to an hypothesis based on this assumption that I now wish to direct attention.

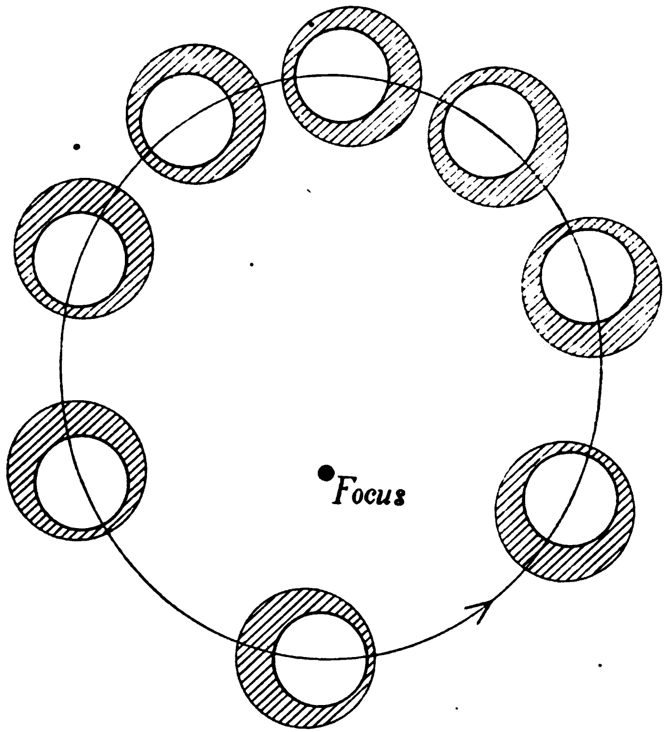
The idea that the variation of light is due to a variation of absorption gains in weight when we recall the similarity between the light- and velocity-curves of these stars, which has been well known since the first orbits were determined and which is especially striking in the case of W *Sagittarii.* The light-curves of stars are ordinarily drawn with ordinates measured in terms of "magnitudes" or other units which express, not the actual amount of light, but the intensity of the observer's sensation, which is proportional to the logarithm of the light. Hence, the similarity of the light-curves and the velocity-curves indicates that the logarithm of the light, and not the light itself, is proportional to the radial velocity. Now, for an absorbing medium of uniform density, the logarithm of the light varies as the thickness, the law of absorption being

$$\log \frac{E}{I} = -\beta x,$$

where x is the thickness of medium traversed, β the coefficient of absorption, and E and I the respective intensities of the emergent and incident light. Therefore, the star's light variation may be explained by assuming an absorbing atmosphere whose depth on the side toward the observer is, within appropriate limits, inversely proportional to the component of the velocity in that direction.

The principal requirements of the case may be met if we suppose a very rare envelope of nebulous matter to surround the darker star of the pair, and that the atmosphere of the brighter component is brushed backward by the friction of this medium so that its depth on the advancing side is less than that on the following. It seems to me to be possible that the Sun's corona is an envelope like this and that coronæ of equal or perhaps greater density may surround all stars of the solar and more advanced types. The orbits of *Cepheid* stars are probably all very much smaller than the orbit of *Mercury* ($a \sin i$ averages about 1,500,000^{km}, while *Mercury's* mean distance is 58,000,000^{km}), and it may be that at a distance from the Sun itself equal to the mean distance between the average *Cepheid* pair the corona would be dense enough to produce the observed effects. If we suppose the absorbing atmosphere of the lucid star to be of low specific gravity, then the envelope of the darker component need not be dense enough to produce by its friction a perceptible shortening of the period.

The shape assumed by the moving star's atmosphere in different parts of the orbit is rudely represented in the figure. The ellipse in the figure has an eccentricity of about one third, which is near the average eccentricity of the *Cepheid* orbits. The atmosphere is represented as spherical but eccentrically placed with regard to a moving spherical star—a condition which is of course only approximately realized. From the figure it is easy to see that maximum light will always occur near the time of minimum positive velocity, and minimum light near maximum positive velocity. The synchronism should be exact if there are no disturbing influences and if the orbit is circular or the resistance varies exactly as the inverse first power of the velocity; for then the depth of the star's atmosphere, measured in any direction, should be inversely proportional to the resolved part of the velocity in that direction. If, however, the resistance varies inversely as the velocity raised to any higher power than the first, and if the orbit be eccentric, then exact synchronism will not hold. In that case, for values of ω between 0° and 180°, the body will be approaching periastron and the distortion of the atmosphere increasing when it is receding from the observer, and *vice versa;* so that maximum



light should occur a little before velocity minimum and minimum light a little after velocity maximum. For values of ω between 180° and 360°, these conditions should be reversed. An inspection of Table III shows a tendency towards fulfillment of this rule, though there are several exceptions. These may be due to several causes, such as inaccuracy of the orbits or of the photometric observations, inequality of density in different parts of the nebulous envelope, and inequalities of brightness on different parts of the star's surface. In several cases the disagreement in the epochs of maximum or minimum light according to different observers would indicate an uncertainty in those epochs sufficient to account for the exceptions to our rule.

The range of light variation will depend on two factors: the specific absorbing power of the bright star's atmosphere,

TABLE III.—VARIABLE STARS OF THE *CEPHEID* AND *GEMINID* TYPES WHICH ARE KNOWN TO BE BINARY.

Star	α 1900.0	δ 1900.0	Max.	Min.	*V* km	*V'* km	*K* km	*e*	ω	*T*	*U*	*a* sin *i*
RT *Aurigæ*	6h 22m.1	+30° 34′	4.9	5.9	+21.5	+11.7	17.3	0.36	92°.0	3d.4	3d.73	826,000km
ζ *Geminorum*	6 58 .2	+20 43	3.7	4.3	+ 6.8	− 5.7	13.2	0.22	333	6 .4	10 .15	1,798,000
l *Carinæ*	9 42 .5	−62 3	3.6	5.0				0.3±			35 .53	
X *Sagittarii*	17 41 .3	−27 48	4.4	5.0	−15±	− 5±	15.8±	0.45±	90 .4±	6 .3	7 .01	
Y *Ophiuchi*	17 47 .3	− 6 7	6.2	7.0	− 5.0	+10.8	8.5	0.10	209 .2	2 .6	17 .12	1,999,000
W *Sagittarii*	17 58 .6	−29 35	4.6	5.4	−28.6	−18.6	19.5	0.32	70 .0	6 .7	7 .59	1,930,000
Y *Sagittarii*	18 15 .5	−18 54	5.8	6.6	+ 4.0	+17.0	19.0	0.16	32 .0	4 .5	5 .77	1,485,000
κ *Pavonis*	18 46 .6	−67 21	3.8	5.2							9 .09	
U *Aquilæ*	19 24 .0	− 7 15	6.2	6.9							7 .02	
SU *Cygni*	19 40 .8	+29 1	6.5	7.2	−33.4	−14.2	25±	0.21	345 .8	2 .5	3 .85	1,350,000
η *Aquilæ*	19 47 .4	+ 0 45	3.7	4.5	−14.2	+ 4.2	20.6	0.49	68 .9	6 .2	7 .18	1,545,000
S *Sagittæ*	19 51 .5	+16 22	5.4	6.1	−12.5	+ 5.8	19±	0.35	69 .9	1 .3	8 .38	2,000,000
T *Vulpeculæ*	20 47 .2	+27 52	5.5	6.5	− 1.3	+15.9	17.6	0.43	111	3 .8	4 .44	969,000
δ *Cephei*	22 25 .4	+57 54	3.7	4.6	−18	− 5	20.5	0.46	272 .3	4 .8	5 .37	1,300,000

TABLE III (*Continued*).—VARIABLE STARS OF THE *CEPHEID* AND *GEMINID* TYPES WHICH ARE KNOWN TO BE BINARY.

Star.	$Min._v$-$Max._1$	$Max._v$-$Min._1$	Discoverer of Light-Variability.	Discoverer of Binary Character.	Authority for elements of Orbit.
RT *Aurigæ*	$+0^d.16$	$+0^d.36$	ASTBURY	DUNCAN	DUNCAN, *Lick Obsy. Bull.*, **5**, 86, 1909.
ζ *Geminorum*	$-0\ .2$		SCHMIDT	CAMPBELL, BÉLOPOLSKY	CAMPBELL, *Astroph. Jour.*, **13**, 90, 1901.
l *Carinæ*	$-2\frac{1}{2}\pm$		GOULD	WRIGHT	ALBRECHT, unpublished.
X *Sagittarii*	$-0\ .2\pm$	$-1\ .3\pm$	SCHMIDT	SLIPHER	MOORE, *Lick Obsy. Bull.*, **5**, 111, 1909.
Y *Ophiuchi*	$-1\ .3$	$+0\ .5\pm$	SAWYER	ALBRECHT	ALBRECHT, *Lick Obsy. Bull*, **4**, 132, 1907.
W *Sagittarii*	$-0\ .1$	$+0\ .2$	SCHMIDT	CURTISS	CURTISS, *Lick Obsy. Bull.*, **3**, 36, 1904.
Y *Sagittarii*	$+0\ .78$	$+0\ .1\pm$	SAWYER	CURTISS	DUNCAN, *Lick Obsy. Bull.*, **5**, 85, 1909.
κ *Pavonis*			THOME	WRIGHT	
U *Aquilæ*	$-0\ .5$		SAWYER	ALBRECHT	
SU *Cygni*	$+0\ .22$	$+0\ .02$	MÜLLER and KEMPF	MADDRILL	MADDRILL, unpublished.
η *Aquilæ*	$-0\ .2$		PIGOTT	BÉLOPOLSKY	WRIGHT, *Astroph. Jour.*, **9**, 59, 1899.
S *Sagittæ*	$-0\ .22$	$+0\ .4$	GORE	CURTISS	MADDRILL, unpublished.
T *Vulpeculæ*	$+0\ .3$	$+0\ .1$	SAWYER	FROST	ALBRECHT, *Lick Obsy. Bull.*, **4**, 135, 1907.
δ *Cephei*			GOODRICKE	BÉLOPOLSKY	BÉLOPOLSKY, *Astroph. Jour.*, **1**, 160, 1894.

and the ratio of depth of that atmosphere on the front and rear sides of the star; and the latter in turn will depend also on two factors: the relative densities of the atmosphere and the nebulous envelope through which it is dragged, and the speed of the star. To produce a variation of 0.8 magnitude—*i. e.* in order that the light at maximum shall be double that at minimum, it is of course necessary that the atmosphere on the following side absorb at least half the light emanating from that side of the star, and even with that degree of absorbing power the front side of the star must be laid wholly bare. If, however, the atmosphere on the following side absorb three fourths of the incident light, it need be only twice as deep as that on the preceding side in order to produce the above variation. The atmosphere of the Sun, according to LANGLEY, absorbs from one half to four fifths of the light passing normally through it, the absorption being greatest in the blue end of the spectrum.

Dr. ALBRECHT's discovery that the maximum intensity of the spectrum of a *Cepheid* variable is shifted toward the violet as the star approaches maximum and redwards again as minimum approaches, is in agreement with the hypothesis of absorption. HALE and ADAMS[19] find a more distinct example of the same phenomenon in their comparison of the spectra of the center and limb of the Sun, in that it was necessary to expose eight to ten times as long at the limb as at the center for the violet, but only four or five times as long at the limb as at the center for the red.

It will be of interest to compare spectrograms of the same star made at maximum and minimum to find out if there be any such changes as HALE and ADAMS found in the solar spectrum in moving from the Sun's center to its limb. None of the plates obtained with the single-prism instrument lends itself to this purpose on account of the low dispersion, and the spectrograms that I obtained of RT *Aurigæ* were taken with too wide a slit.

By an inspection of Professor WRIGHT's plates of η *Aquilæ*, made with the 3-prism Mills spectrograph, Dr. ALBRECHT[20]

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[19] *Contributions from Mount Wilson Solar Observatory*, No. 17.

[20] *Lick Observatory Bulletin*, 4, 131, 1907.

found variations in the position of spectral lines as the star's light phase changed from maximum to minimum, which correspond to the changes which he observed in passing from one spectral type of star to another;[21] and the appearance at light minimum corresponds to that of an older-type spectrum, thus indicating an increase of absorption at minimum.

If the nebulous envelope which I have supposed to exist about the darker star be similar to the Sun's corona, we may expect the form of the light-curve to vary slightly in a period of several years, since the form of the corona, and hence the relative density of its different parts, vary in a similar period. Such a change has been suspected by CURTISS in the case of W *Sagittarii,* and may to some extent account for the dissimilarity of the light-curves of other stars, derived from sets of observations made several years apart. However, in the present state of photometric work, this question cannot be decided.

In Table III is given a list of such variable stars of the δ *Cephei* and ζ *Geminorum* types as are known to possess a variable radial velocity, together with their orbital elements and such other data as I have thought might be of interest. Column one contains the star's name, columns two and three its position for 1900.0, and the two following columns its magnitude at maximum and minimum brilliancy. V is the velocity of the binary system relative to the Sun, and V' that velocity corrected for the solar motion, or the system's velocity relative to the system of brighter stars about us. K is the single amplitude of the velocity-curve, e the eccentricity, ω the argument of periastron measured in the direction of orbital motion from a fundamental plane at right angles to the sight line, T the time of periastron passage in days after light maximum, U the period of orbital revolution in days, and $a \sin i$ the orthographic projection of the semi-axis major upon the YZ plane. The fourteenth column gives the interval in days from maximum light to minimum velocity of recession, and the fifteenth the interval from minimum light to maximum velocity of recession. The last three columns give the names of the discoverer of

[21] *Lick Observatory Bulletin*, 4, 90-95, 1906.

light variability, the discoverer of variability of radial velocity, and the authority for the orbital elements given.

It is with pleasure that I acknowledge my indebtedness to Director CAMPBELL, who placed at my disposal the necessary instruments, and who also aided me with advice and encouragement; to Messrs. WRIGHT, MOORE, and ALBRECHT for various suggestions in discussing the hypotheses regarding stellar variability; to Professor CRAWFORD, of Berkeley, who verified the mathematical work; and to Misses HOBE and ALLEN, who performed a part of the computation.

J. C. DUNCAN.

MT. HAMILTON, May 25, 1909.

THE ORBIT OF THE *CEPHEID* VARIABLE STAR X *SAGITTARII*.[1]

The variable brightness of X *Sagittarii* was discovered by SCHMIDT in 1886. Its variability was soon recognized to be similar in type to that of δ *Cephei*, characterized by a regular and continuous change in light, and the inequality of the intervals from maximum to minimum and minimum to maximum.

The variable radial velocity of X *Sagittarii* was detected by Mr. V. M. SLIPHER[2] from his measures of the plates of June 19 and 22, 1904. A series of spectrograms of this star was secured at the Lick Observatory in August, September, and October, 1904, with the one-prism spectrograph equipped with a light 60° prism.[3] The period being so nearly commensurable with a day, these observations were sufficient to determine only seven points of the curve. It was then necessary to wait until the summer of 1905 before observations at intermediate points of the curve could be secured. When the 1904 and 1905 series were measured and reduced by the method described by Mr. R. H. CURTISS[4] it was found that the accordance of the observations, using all of the plates, was not satisfactory, due to differences in exposure, combined with

[1] A detailed account of this investigation will be found in *Lick Observatory Bulletin*, 157, **5**, 111, 1909.

[2] *Lowell Observatory Bulletin*, **11**, 1904, and *Astrophysical Journal*, **20**, 146, 1904.

[3] For a description of the one-prism instrument, see Mr. R. H. CURTISS's article, *Lick Observatory Bulletin*, **3**, 19, 1904.

[4] *l. c.*

the poor character of the lines in the star spectrum. Accordingly a series of ten plates was secured, in the summer of 1908, with the Mills spectrograph (three-prism), using a slit-width of 0.05^{mm} (which is about 0.010^{mm} to $.014^{mm}$ wider than is used in the regular observing with this instrument), and the very rapid Lumière Σ plates. With the exception of one plate, which was badly underexposed, the three-prism series was capable of accurate measurement.

The final procedure was to measure only the best plates taken with one prism (the 1904 and 1905 series) and the new series of three-prism plates.

After a number of trials the following elements were decided upon as giving the best representation of the observations:

$$
\begin{aligned}
U &= 7.01185 \text{ days (assumed)} \\
\mu &= 51^{\circ}.342 \\
e &= 0.40 \\
\omega &= 93^{\circ}.65 \\
T &= \text{J. D. } 2416723.05 \\
a \sin i &= 1{,}334{,}000^{km} \\
V = \text{velocity of system} &= -13.50^{km}
\end{aligned}
$$

The epoch of greatest velocity of approach is 0.28 day later than the time of light maximum. The close agreement of the times of light maximum and of the greatest velocity of approach is a fundamental characteristic of all variables of the *Cepheid* type, as pointed out by Mr. ALBRECHT.[5] There seems to be no close connection in the case of X *Sagittarii* between the time of minimum light and that of the greatest velocity of recession, the minimum in the light-curve preceding the time of greatest positive velocity by about 1.7 days. This connection does not appear, however, to be such a close one as that for maximum light and greatest negative velocity in the case of other *Cepheid* variables. The smooth character of the light- and velocity-curves of X *Sagittarii* is worthy of note. Evidently if any irregularities exist in either, they are quite small.

J. H. MOORE.

MT. HAMILTON, April 19, 1909.

[5] *Lick Observatory Bulletin*, **4**, 130, 1907.

THE SPECTRA OF SOME SPIRAL NEBULÆ AND GLOBULAR STAR CLUSTERS.[1]

This investigation was undertaken to test the correctness of the statement frequently found in astronomical literature that the spectra of the spiral nebulæ are continuous, and to increase our knowledge of these spectra in any manner possible. A few globular star clusters were added to the program for reasons given below.

There are but two published observations, as far as known, which cast any doubt on the continuous character of the spectra of spiral nebulæ—one by SCHEINER[2] and the other by HUGGINS,[3] both of whom worked on the *Andromeda* nebula. Each of these observers obtained a spectrogram showing absorption lines: the former, lines corresponding to G (λ 4308) and H (λ 3969) of the solar spectrum; the latter, the G, H, and K (λ 3934) lines, with some others not named. The spectrogram by SCHEINER was probably faint and there may be some doubt as to its interpretation, for the late Director VOGEL, who presumably saw the plate, when revising NEWCOMB-ENGLEMANN'S *Populäre Astronomie* several years later, said on page 577: "Selbst über das Spektrum des bekannten Andromedanebels ist nichts weiter bekannt, als dass er nicht das sonst bei Nebeln gewöhnlich vorkommende Gasspectrum zeigt." HUGGINS does not seem to think his plate entirely free from suspicion, for he says:[4] "The photograph . . . we had put aside . . . as probably vitiated, in some unknown way, by the coming in of direct solar light, or of moonlight." The basis for this suspicion is due to the fact that an overexposed solar spectrum was imprinted on the same plate for comparison. HUGGINS also observed visually some bright lines in the spectrum of this nebula.

These two photographic observations agree in showing absorption lines present in this nebular spectrum; but, judging from the circumstances as noted, the evidence can hardly be called conclusive.

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[1] Abstract of *Lick Observatory Bulletin*, No. 149.

[2] *Astronomische Nachrichten*, **148**, 325, 1899.

[3] *Atlas of Representative Stellar Spectra*, p. 119, 1899.

[4] *Atlas of Representative Stellar Spectra*, p. 126.

The telescope used in the present investigation was the Crossley reflector.[5] Some preliminary work by the writer, in the summer of 1907, with this telescope and a small quartz spectrograph, on the *Andromeda* nebula promised interesting results. Accordingly a special spectrograph[6] was designed for efficiency in observing such faint objects, using optical and other materials in part already on hand.

The extremely feeble intensity of the light of the spiral nebulæ, even the very brightest, is hard to realize. A comparison of stellar spectrograms taken with the instruments used in this investigation and those made with the Mills spectrograph attached to the 36-inch refractor shows that the latter requires from twenty to thirty times as long an exposure as the former to obtain spectrograms of the same density, using the same slit-width in both cases.[7] Assuming the ratio of the exposures as 1 :25, and using a slit-width of 0.08^{mm} and Lumière Σ plates, it would take an exposure of 450 hours with the Mills spectrograph to obtain a satisfactory plate of the brightest part of the *Andromeda* nebula, which is one of the brightest of the spirals. This statement is based on plate 45, which is of about the proper density. It is further based on the favorable assumption that for a spectrum of given intensity the exposure time varies inversely as the intensity of the light falling on the plate. As is well known, this is not the case, so that a 500-hour exposure would probably be nearer the truth. Under similar conditions a plate of *Arcturus,* which is of the same spectral type, could be secured with the Mills spectrograph in less than two minutes.

The results of this preliminary investigation may be summed up in the statement: No spiral nebula investigated has a truly continuous spectrum. While this may be a step in advance, nevertheless it is wholly inadequate to answer the question

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[5] For a description of this telescope with its present mounting, see *Lick Observatory Bulletin,* **3**, 124, 1905.

[6] For a description of this spectrograph, an account of the methods of observing, and of the details of the results obtained, the reader is referred to the original paper.

[7] The purity, of course, would be vastly different owing both to the difference in focal lengths of the respective collimator lenses and the great difference in dispersion.

as to the real nature of these interesting objects which the work of Keeler brought so prominently before the astronomical world. Their spectra vary from those having principally bright lines such as are found in the gaseous nebulæ to those containing only absorption lines of the solar type.

In trying to interpret these results it must be remembered that the spectrograms obtained record only the spectra of the denser central portions of the nebulæ. In the case of the *Andromeda* nebula this amounts to five minutes of arc. Then, too, the very low dispersion of the spectrograph used undoubtedly masks much that is of fundamental importance. Whether the spiral arms will give the same spectrum as the central portion is a question which will be difficult to answer with present appliances.

Careful consideration has been given to various hypotheses to account for the character of the spectra photographed. Only one hypothesis seems at all tenable, and serious objections can be advanced against this one. It may be termed the "star-cluster" theory, reached by the following considerations.

The only known sources of continuous spectra are luminous solids, liquids, very dense gases, or possibly masses of gas of great thickness. To produce bright lines or bands we require gases or vapors rendered luminous by heat, electric discharges or chemical change, or substances made to fluoresce by energy supplied by some external agency. For absorption lines or bands to be present the necessary condition is an absorbing medium, usually of a gaseous nature, between a source of continuous radiation and the observer. These are, for the most part, well established experimental facts.

The primary or fundamental part of the spectra of the spiral nebulæ is a continuous background. This is interrupted by absorption lines, and superimposed upon it in some cases are bright lines or bands. The matter producing the lines, bright or dark, must be assumed to lie between the source of continuous radiation and the observer. Hence we conclude this source to be surrounded by a gaseous envelope, of physical condition varying in the different nebulæ and corresponding to the various spectra obtained. The only celestial bodies of this type with which we are acquainted are the stars.

The hypothesis that the central portion of a nebula like the famous one in *Andromeda* is a single star may be rejected at once unless we wish to modify greatly the commonly accepted ideas as to what constitutes a star. Assuming, however, an unresolved star cluster consisting of stars mainly of solar type we would seem to have a sufficient explanation of the spectrograms of the *Andromeda* nebula. But the question arises: Is it reasonable to assume that in a condensed cluster we should have stars of one spectral type strongly predominating?

In seeking an answer to this question I have found but two references to observations of the spectra of known dense star clusters. These are not sufficiently definite to settle the matter. HUGGINS,[8] in reporting an observation on the great cluster in *Hercules,* says: "Spectrum of central blaze continuous. Spectrum ends abruptly in the orange. The light of the brighter part is not uniform; probably it is crossed by bright lines or lines of absorption." VOGEL[9] likewise observed this cluster and writes as follows: "Der bekannte Sternhaufen im *Hercules* zeigte ein sehr schwaches continuirliches Spectrum, welches sich von ca. 620 bis 450 Milliontel Millimeter verfolgen liess. In demselben waren einige dunkle Streifen zu erkennen, konnten aber wegen zu grosser Lichtschwäche nicht gemessen werden."

It was accordingly necessary to investigate some known star clusters. From the Crossley negatives three dense clusters were selected for trial—N. G. C. 6205, 7078, and 7089. The first, the famous cluster in *Hercules,* gave evidence of containing stars of different spectral types, while the other two gave F-type spectra only. Photographs show clusters such as these to be made up of two groups of stars,[10] the one of magnitudes 11 to 13 and the other of about magnitude 16. The brighter group was probably the only one giving the spectrograms. If we could view such a cluster from a distance so great that it could not be resolved into its component stars

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[8] *Philosophical Transactions,* **156**, 389, 1866.

[9] *Astronomische Nachrichten,* **78**, 245, 1871.

[10] *Lick Observatory Bulletin,* **3**, 49, 1904, and *Astrophysical Journal,* **20**, 354, 1904.

there is no question but that it would continue to give such spectrograms as have been described. We thus have the question as to whether clusters can be found in which stars of one spectral type predominate answered in the affirmative.

The "star cluster" interpretation of the results obtained stands or falls by the question of parallax. It does not seem reasonable to assume stars that should be many times smaller than the Sun. We also require the cluster to be at such a distance that it cannot be resolved. Now the only determination of the parallax of a spiral nebula that the writer has been able to find is that of the *Andromeda* nebula by BOHLIN.[11] He finds this to be $0''.17$. His result rests on two separate determinations, each of which gave positive values for the parallax both in α and δ. The result is therefore entitled to some confidence. If, now, the parallax of the *Andromeda* nebula is of this order of magnitude, the "star-cluster" theory, at least for this particular object, is not very satisfactory. For, assuming this parallax; a surface brilliancy of the component stars equal to that of the Sun; and a ratio of brightness of the central portion of this nebula to that of the Moon of 1/180,000 (derived from Crossley negatives): a simple computation shows that if the stars are so closely packed as to be irresolvable their dimensions are of the order of the asteroids; while if assumed only as large as *Jupiter* they would appear some seconds of arc apart. This is not found to be the case. The "star-cluster" theory, however, seems to be the only one that can at all adequately explain the spectrum obtained, and another determination of the parallax, preferably by another observer with a different instrument, would be of great interest.

The theory as given above is not a new one, but with the exception of the work of SCHEINER and HUGGINS on the *Andromeda* nebula there were no facts, so far as the writer has been able to find, to support it. Even now the material is very meager and more questions have been raised than answered. We still know nothing concerning the spectra of the spiral arms and little or no light is shed on the fundamental questions of the origin of the spiral nebulæ, their relations

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[11] *Astr. Iaktt. o. Unders. A Stockholms Obs.*, **8**, No. 4, 66, 1907.

among themselves, and to other stellar objects. These questions must be left for the future.[1]

E. A. Fath.

Mt. Hamilton, December, 1908.

Note on the Classification of Double Stars.

Lick Observatory Bulletin, Number 158, contains another list of one hundred new double stars discovered and measured with the 36-inch telescope. This list brings the total number of my published discoveries to two thousand. Arranging these stars according to their angular separation, we have the following table:—

Distance	No. of Pairs	Percentage
0″.25 or less	182	9.10
0 .26 to 0″.50	444	22.20
0 .51 to 1 .00	400	20.00
1 .01 to 2 .00	450	22.50
2 .01 to 5 .00	511	25.55
5 .01 or greater	13	0.65
	2000	100.00

From this table it appears that more than one half (51.3%) of the stars listed belong to Struve's Class I (distance 1″ or less), and that nearly three fourths (73.8%) fall within the 2″ limit. The thirteen pairs which exceed the limit 5″.0 have components whose difference in brightness averages 5.7 magnitudes. In only three cases does the angular separation exceed 5″.2. Though the program of my survey contemplates the systematic examination of the stars only to the magnitude 9.0, inclusive, it is inevitable that fainter stars should from time to time be brought into the field of the telescope. In this way many fainter pairs have been discovered, but, in general, only the very close ones have been listed. In all, I estimate that considerably less than 10 per cent of the pairs published have components whose combined brightness falls below 9.0 B. D. magnitude.

[1] The publication of the above paper was unavoidably delayed. Since it was written Professor Barnard has published the results of a photographic investigation of the *Hercules* cluster in the *Astrophysical Journal,* **29**, 72, 1909. He finds that this cluster is composed of stars of different spectral types. The spectrographic results obtained by the writer are in agreement with this.

E. A. Fath.

March, 1909.

Excluding the stars south of —30° Declination, I find by examining the various double-star catalogues that there are about 7,500 known pairs with measured distances of 5″ or less. This is an estimate only, but as care was taken to include all published lists and to make the estimates liberal I think the number given is certainly large enough. Of this number about 4,400 have distances under 2″, and 2,550 of these are under 1″. These figures are more nearly exact than the general total. The survey now in progress at this observatory has contributed 3,300, 2,460, and 1,700, respectively, to these totals. Nearly 60 per cent, therefore of the 7,500 pairs under 5″ are under 2″, and this percentage will be raised at the completion of our survey, for nearly 75 per cent of the 3,300 pairs already found here belong to the closer class. In other words, the actual number of very close double stars (distances under 2″) greatly exceeds the number with moderate separation (distances between 2″ and 5″). We are, of course, reasoning from incomplete data, but so far as this affects our argument it favors the opposite conclusion, for it is the exceptionally close pairs and those under 2″ with one component relatively faint which are the ones most likely to have escaped detection. The spectroscopic binaries must also be taken into account and they all belong to the very close pairs. Keeping in mind the proportion of the known spectroscopic binaries to the stars whose radial velocities have been measured, and remembering that this percentage is certain to be increased by the addition of spectroscopic binaries hitherto undetected because of smaller range of radial velocity or longer period, it is safe to say that the double stars (visual and spectroscopic), among the stars to the magnitude of 9.0 inclusive, with distances under 2″ outnumber those with distances between 2″ and 5″ in the proportion of 3 to 1.

This conclusion, based upon data supplied by observation, confirms in the strongest manner the argument from the theory of probabilities that practically all of the closer double stars are binary systems. Certainly we may reasonably assert that a double star with an angular separation of less than 2″ is a binary until the contrary has been demonstrated instead of suspending judgment until definite orbital motion has been observed.

R. G. Aitken.

Mt. Hamilton, April 29, 1909.

REPORTS OF OBSERVATORIES.[1]

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

During the year 1908 Mr. SHELTON SWAN and the Director devoted all the time that could be spared from other duties to comet and asteroid observations. Miss MYRTLE RICHMOND, a graduate student in the University of Denver, devoted much time to the reduction of observations, which are now ready for publication.

HERBERT A. HOWE, *Director.*

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

Regular observation for the variation of latitude was continued throughout the year 1908. The observing program was that used in 1906 and 1907; assigned by the International Geodetic Association for the period of four years following 1906.0.

The continuity of the work was satisfactory, but was somewhat interrupted in the summer by the heated air and smoke from the most serious brush fires that have visited the immediate vicinity of the observatory since its establishment.

Subsidiary observations and reductions made from time to time indicated uniformly excellent stability of the instrument and constancy of its factors, and entirely satisfactory observational results.

JAMES D. MADDRILL,
Astronomer-in-Charge.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

Inasmuch as the Director's reports to the President of the University of California date from July 1st, the beginning of the academic year, the annual reports appearing in these *Publications* will be for the twelve months beginning with July 1st, save that the series will be inaugurated by a report covering the period January 1, 1908, to July 1, 1909. This report will appear in the number for August.

W. W. CAMPBELL, *Director.*

[1] Arranged alphabetically according to name.

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

The work of this observatory during the past year has continued about the same as in former years. The usual number of chronometers has been rated and issued to ships in the naval service and the time service has been maintained as heretofore. By courtesy of the Director of the Lick Observatory, in connection with the co-operation of the Bureau of Equipment, the longitude of the observatory was redetermined in May, 1908, by Professor R. H. TUCKER and Mr. SANFORD from Mount Hamilton. The new seismograph of the Bosch-Omori type, recently purchased, is being mounted in a suitable room, on heavy solid foundations, and it is believed that it will give very satisfactory records of earthquakes. The officer in charge of the observatory has been able to bring to a successful conclusion certain researches on the origin of the solar system, with which he has been occupied for many years. A preliminary report of this work has been printed in the *Publications* of the Astronomical Society of the Pacific, No. 126, and in the *Astronomische Nachrichten,* No. 4308.

T. J. J. SEE,
Professor of Mathematics, U. S. Navy, in Charge.

SOLAR OBSERVATORY, MOUNT WILSON, CALIFORNIA.

The continuation and extension of the researches described in my last annual report have led to the following results:—

(1) The comparative study of the spectra of the limb and center of the Sun favors the conclusion that the relative displacements of the lines near the limb (after eliminating the Doppler effect) are mainly due to pressure. Further laboratory work is required before a final decision can be reached.

(2) The angular velocity of the solar rotation, as determined from the motions of the calcium (H_2) flocculi on the spectroheliograph plates, decreases from the equator toward the poles. The mean velocity at any latitude is very nearly the same as that of the sun-spots.

(3) The angular velocity of the solar rotation, as determined from the motion in the line of sight of the hydrogen represented by dark lines in the solar spectrum, is more rapid at the equator than the angular velocity of the spots and calcium (H_2) flocculi, and decreases less rapidly toward the poles.

(4) The hydrogen ($H\delta$) flocculi, as measured on spectroheliograph plates, move at the equator with about the same angular velocity as the calcium (H_2) flocculi, and show no evidence of retardation toward the poles. This result was obtained before the discovery of solar vortices, and must be tested by measurements of the motions of $H\alpha$ flocculi lying outside of the vortices.

(5) Investigations with an electric furnace have shown that such changes of relative intensity as are exhibited by the lines of iron, titanium, and other substances in sun-spots are produced by lowering the temperature of the furnace. This is in harmony with our conclusion that the temperature of these vapors in sun-spots is lower than in the reversing layer outside of spots.

(6) The flutings of calcium hydride, as observed in another form of electric furnace, have been identified with flutings in our photographs of sun-spot spectra.

(7) Through the use of the $H\alpha$ line of hydrogen, it has become possible to photograph a hitherto unexplored region of the solar atmosphere. The photographs show that sun-spots are surrounded, and perhaps produced, by extensive vortices.

(8) The components of double lines photographed in the spectra of sun-spots with the 30-foot spectrograph of the tower telescope have been found to be circularly polarized in opposite directions. This and much other evidence proves that sun-spots contain a strong magnetic field. By means of spectrographic observations the areas, strengths, and polarities of these fields can be measured, thus permitting a magnetic survey of the entire visible hemisphere of the sun to be made.

In addition to these investigations, much work of research described in other parts of this report has been done, and the work of construction has advanced very satisfactorily. A spectroscopic laboratory in Pasadena, equipped for investigations requiring very high temperatures and pressures, was completed and occupied in March. The 60-inch reflector has been erected.

STAFF.

Mr. W. S. Adams has continued his work as superintendent of the computing division, and Mr. G. W. Ritchey has had

charge of construction, both in Pasadena and on Mount Wilson. Dr. ARTHUR S. KING, formerly of the University of California, has been appointed superintendent of the physical laboratory, and commenced work on January 1st. Dr. CHARLES E. ST. JOHN, formerly professor of physics and dean of Oberlin College, joined our staff in May. Mr. FERDINAND ELLERMAN has continued his work with the Snow telescope. Since the completion of the Pasadena laboratory, Dr. OLMSTED has carried on his spectroscopic work there. Miss LOUISE WARE, Miss JENNIE B. LASBY, Miss RUTH E. SMITH, and Miss CORA G. BURWELL have continued their study of photographs in the computing division. Miss LILLIAN M. WICKHAM joined the staff of the computing division on February 1st.

Professor ERNEST F. NICHOLS, Research Associate of the Carnegie Institution of Washington, has been engaged in an investigation of the absorption of the Sun's atmosphere and in laboratory investigations on Mount Wilson during the summer of 1908. Dr. WALTER M. MITCHELL, director of the Haverford College Observatory, and Mr. H. C. PLUMMER, of the Oxford University Observatory, have also spent some time on Mount Wilson, for the purpose of becoming familiar with the investigations in progress.

The work of the Smithsonian Expedition, carried on by Mr. ABBOT during the summers of 1905-06, was renewed on Mount Wilson in May and is still in progress. Mr. ABBOT is assisted in this work by Mr. LOUIS B. ALDRICH, of the University of Wisconsin. It is a satisfaction to state that arrangements have now been made by the Smithsonian Institution to construct a permanent station on the mountain, where studies of the solar constant and other investigations will be continued regularly in the future.

INVESTIGATIONS IN PROGRESS.

Direct Photography of the Sun.—Direct photographs of the Sun have been made daily, as heretofore, with the Snow telescope.

Work with the Spectroheliograph.—The total number of photographs of the Sun taken with the 5-foot spectroheliograph amounted, on September 30th, to 5,196. In March, through

the use of plates sensitized for the red by Wallace's process, it became possible to take photographs with the *Hα* line of hydrogen. These were found to differ in important respects from those obtained with *Hδ*. As it soon appeared that the *Hα* images gave a much more complete record of the hydrogen flocculi, mainly because of the great strength of this line in the upper chromosphere and prominences, where *Hδ* is weak, the former line was selected for the daily records, in place of *Hδ*. This change soon led to the discovery that sun-spots are surrounded by vortices, which occur in a region of the solar atmosphere higher than that recorded on *Hδ* plates. A full account of this work, illustrated with photographs of the vortices, may be found in No. 26 of the *Contributions from the Mount Wilson Solar Observatory*.

As the rapid changes in the vortices required that many photographs be made at short intervals, it became necessary to improve the performance of the Snow telescope and to modify the daily program of observations so as to include more *Hα* plates. As the result of experiment it was found that the reduction of the aperture of the cœlostat to 15 inches, while it only partially cured the rapid change of focal length caused by exposure of the mirrors to the Sun, almost completely eliminated such evidences of astigmatism as had seriously injured earlier photographs. For this reason all *Hα* exposures are now made with the 15-inch aperture. The early morning observations are devoted exclusively to the photography of the disk with the *Hα* line. In the late afternoon additional *Hα* plates of the disk are taken, together with one prominence plate (using *Hα* in place of H_2, the line formerly employed), one H_1 disk and one H_2 disk.

The remarkable sharpness of the best *Hα* plates, and the evidence they invariably afford of the existence of definite vortices and currents in the solar atmosphere, have led to many important developments in our work with the spectroheliograph. It now becomes feasible to undertake a systematic examination of sun-spot theories, and to pursue many investigations hitherto out of reach.

Miss WARE's measurements of the motions of 1,680 points in the calcium (H_2) flocculi, made with the heliomicrometer

on fifty-one negatives, taken with the 5-foot spectroheliograph during the period June 18th to September 22, 1906, have given the following results for the mean angular rotations (sidereal), corresponding to 5° zones (Table 1). The means in the table combine the results for corresponding latitudes in the northern and southern hemispheres, reduced from synodic to sidereal values.

Miss WARE has also measured the motions of 828 points in the hydrogen flocculi on thirty-five $H\delta$ plates (Table 1). The difficulties of identification are much greater than in the case of the calcium flocculi, since the hydrogen flocculi change more rapidly in form. It is thus necessary to use plates separated by an interval of only about twelve hours, whereas the same calcium flocculus may frequently be measured on plates separated by an interval of two or three days.

TABLE I.

	Calcium (H_2).		Hydrogen ($H\delta$).	
Zone.	No. of measures.	ξ	No. of measures.	ξ
0° ± 5°	232	14°.5	129	14°.3
± 5 ± 10	262	14 .3	105	14 .1
± 10 ± 15	317	14 .3	145	14 .4
± 15 ± 20	326	14 .2	120	14 .4
± 20 ± 25	259	14 .2	114	14 .5
± 25 ± 30	153	14 .0	95	14 .6
± 30 ± 35	99	13 .8	61	14 .8
± 35 ± 40	26	14 .0	43	14 .8
± 40 ± 45	6	13 .2	16	15 .2

It will be seen that while the motions of the calcium flocculi clearly show a decrease in angular velocity toward the poles of about the same magnitude as in the case of sun-spots, the hydrogen flocculi do not apear to follow the same law.

This work was near completion when the first $H\alpha$ photographs of the disk were obtained. The extensive whirls shown on these photographs indicate that the flocculi lying in the neighborhood of sun-spots, or within any region occupied by whirls, are unsuitable for the determination of the solar rotation. The $H\delta$ plates apparently represent the hydrogen in a lower region of the solar atmosphere, where the whirls are not clearly shown. Nevertheless, the motions of the $H\delta$ flocculi are probably affected by the whirls, which may account for

many peculiarities encountered in the measurement of the plates. It accordingly becomes necessary to study the rotation at the $H\alpha$ level, by means of flocculi which are well outside of the whirls.

A further extension of the spectroheliograph work will soon be possible, as the 30-foot spectroheliograph, constructed in our instrument-shop during the year, is now nearly ready for trial.

Spectra of Sun-Spots.—Many photographs of spot spectra have been made during the year by Mr. ADAMS and myself. Most of these have been taken in the third order of the 30-foot spectrograph of the tower telescope and are greatly superior to the photographs made with the Snow telescope and 18-foot Littrow spectrograph. Double lines, which appear single in the previous photographs, are now clearly resolved, and a great number of additional faint lines, particularly those of flutings, are recorded. The preparation of a catalogue of the lines shown on the earlier plates was well advanced when the first of the new photographs was obtained. Their superiority has made it necessary to prepare a new catalogue, which will contain a much greater number of lines than the former one.

The hypothesis that the relative intensities of sun-spot lines are determined largely by a reduction in the temperature of the metallic vapors below that of the same vapors in the reversing layer is strongly supported by Dr. KING's work with an electric furnace, described on another page of this report. Dr. OLMSTED's detection of the red flutings of calcium hydride in spot spectra affords additional evidence in the same direction.

The discovery of the solar vortices suggested that the rapid revolution of electrically charged particles (assuming a preponderance of positive or negative ions, resulting from diffusion or other cause) should produce a magnetic field within sun-spots (Rowland effect). Photographs of spot spectra taken with the 30-foot spectrograph and the tower telescope showed a great number of close double lines, many of which had previously been seen visually by YOUNG and MITCHELL, who described them as "reversals." I accordingly examined the components of these lines and found their light to be circularly polarized in opposite directions. This is what would be observed if the vapors giving rise to these lines were seen

along the lines of force of a strong magnetic field. Other spot lines, which are widened but not doubled, were found to be shifted in position when the nicol was rotated. Spot vortices rotating in opposite directions give doublets having components in which the direction of the circular polarization is reversed. Triplets, the central line of which is plane polarized, also occur in spot spectra. These and similar results, confirmed by many laboratory tests, conclusively prove that a powerful magnetic field (2,800 to 4,500 gausses) exists in sun-spots.

Photographic Comparison of the Spectra of the Center and Limb of the Sun.—The completion of the tower telescope, and the much more powerful spectrographic apparatus available with this instrument, led to the transfer of the spectroscopic work on various parts of the Sun's disk from the Snow telescope to the tower. The considerably greater dispersion available has proved to be of particular value in connection with Mr. ADAMS's study of the spectra of the center and limb of the Sun; the quantities measured being so minute as to require the greatest linear scale which it is possible to obtain. In order to secure the two spectra simultaneously, and thus avoid possible errors arising from change of temperature or unequal illumination of the grating in the two positions of the Sun's image on the slit, a special attachment has been constructed for the purpose. Two small diagonal prisms throw light from the edge of the Sun upon the slit, while the light from the center passes unobstructed on either side of the central prism. Photographs taken with this apparatus have proved extremely satisfactory and thoroughly reliable as regards the absolute displacements involved. At the present time negatives are being taken for the purpose of providing a photographic map of the spectra of these two portions of the Sun's disk, and it is expected that this map will be completed some time during the winter.

In addition to the conclusions drawn from the measurement of the displacements referred to in the last report, the important result has been found that the spark or "enhanced" lines in the spectrum seem to show greater displacements at the limb of the Sun than do the majority of the other lines.

This has a vital bearing on the question of the level at which these lines originate in the Sun's atmosphere. It will require, for satisfactory explanation, a series of laboratory investigations on the displacements of spark lines under pressure.

Spectrographic Investigation of the Solar Rotation.—Mr. ADAMS's photographic investigation of the rotation of the Sun, by means of the displacements of the spectrum lines at the opposite limbs, has been continued throughout the year with the powerful spectrograph of the tower telescope. The advantages of this instrument over the 18-foot spectrograph of the Snow telescope, with which the investigation of 1906 to 1907 was carried on, are very considerable. In addition to the superior quality of the solar image, and greater freedom from astigmatism and change of focus, the larger linear scale furnished by the instrument, and the possibility of setting for different position angles, by rotation about a vertical axis, have proved of great value. The plates employed in the study of the rotation from lines in the violet part of the spectrum have all been taken in the third order of the grating. Plates including the region about $H\alpha$ in the red part of the spectrum have been taken in the second order.

About twenty-five plates covering the same region of the spectrum that was employed in the investigation of last year have been measured and reduced. The degree of accuracy obtained seems to be appreciably higher than that secured with the plates from the 18-foot spectrograph. The comparison of the results of the two series of observations indicates very close agreement in the latitudes running from 0° to 45°. From 60° to the pole, however, the values obtained from the present series fall appreciably below those of last year, the difference amounting to about 0.04^{km} at a maximum. It does not at present seem probable that this difference is to be ascribed to a real variation in the rotation of the Sun, since it is not shared in by the zones of lower latitude, in which the activity of the Sun, as indicated by the presence of spots and flocculi, is much greater. A more probable explanation would seem to be that it is due to errors arising in the former series of observations, from astigmatism and other defects of the solar image. The values obtained from the present year's series of observations are now being collected and will be published within a short time.

One of the most important contributions furnished by the investigation of the rotation of the Sun is Mr. ADAMS's discovery that the hydrogen gas producing the α line of hydrogen moves with a decidedly greater angular velocity than the general reversing layer, and seems to be subject to quite a different law from that of the ordinary equatorial acceleration. The first indications that a result of this kind was to be expected were furnished by the study of photographs of the spectra of the center and limb of the Sun, and as soon as these became evident the investigation was continued with the regular rotation apparatus of the tower telescope. The results obtained from the earlier plates of the series are given in Table 2:—

TABLE 2.

	v km	$v+v_1$ km	ξ	Period days
—0°.1	2.07	2.21	15°.7	22.9
9 .3	2.01	2.15	15 .5	23.2
14 .8	1.96	2.10	15 .4	23.4
22 .7	1.90	2.03	15 .6	23.1
29 .7	1.73	1.87	15 .3	23.5
44 .5	1.44	1.55	15 .4	23.4
59 .3	1.04	1.12	15 .6	23.1
73 .5	0.63	0.67	16 .7	21.6

The inclusion of a larger number of results will probably indicate a slight decrease in the value of the angular velocity toward the pole of the Sun, but the law will evidently be very different from that of the reversing layer. It also seems probable that the value of the angular velocity at the equator will be somewhat reduced when a larger series of observations is available.

Some recent work on the blue line of calcium at λ 4227 indicates that the rate of rotation given by this line differs from that of the general reversing layer. A series of photographs obtained especially for the study of this line is now being investigated.

Absorption and Scattering in the Solar Atmosphere.—Professor E. F. NICHOLS, Professor of Physics in Columbia University and Research Associate of the Carnegie Institution of Washington, has just completed an important investigation on Mount Wilson. The object of the work is to determine the

law of absorption and scattering of light in the solar atmosphere. An image of the Sun, formed by the Snow telescope, falls upon a slit. The rays which enter the slit are rendered parallel by a collimating mirror, pass through a large prism, and the spectrum thus formed is brought to a focus by a second mirror. A bolometer, kindly supplied by Mr. ABBOT, is set at a certain wave-length. As the sun's image transits across the slit, the deflections of the galvanometer are recorded on a moving photographic plate. In this way photographed curves, corresponding to a number of different wave-lengths, give a measure of the solar radiation at points along a diameter parallel to the direction of the diurnal motion. Several refinements of the method, which are due to Professor Nichols, should lead to results of high precision. The observations have been completed and will be reduced as soon as possible.

PHYSICAL LABORATORY.

To meet the needs of experimental work, which require the use of electric currents much stronger than can be economically generated on Mount Wilson, the construction of a new physical laboratory, on land adjoining our Pasadena instrument-shop, was begun in the autumn of 1907. On January 1, 1908, the work had progressed as far as the completion of the exterior walls and roof and the excavation of the 30-foot pit in the middle of the floor. During January and February the interior arrangements were for the most part completed, including the cementing and drying of the pit, the laying of the cement floor with conduits for electric wires embedded in the cement, the construction of concrete piers for the apparatus, the installation of the electrical machinery, and the fitting up of the chemical laboratory and dark-room. About March 1st actual investigation work began with the mounting of the 30-foot spectrograph in the pit and the setting up of the large electric furnace, the construction of which had been completed in the machine shop after being received from the maker. A description of the laboratory may be found in *Contributions from the Mount Wilson Solar Observatory*, No. 27.

The electric furnace quickly yielded results which demonstrated its superiority for spectroscopic work over any existing

apparatus of the kind. The work so far carried on by Dr. KING has included a study of the spectra of iron, chromium, titanium, and vanadium, as given by the furnace in vacuum at different temperatures. The effect of temperature and different amounts of vapor upon the principal lines of calcium was also observed. A series of measurements were made with an optical pyrometer to obtain the temperatures at which the various spectra were produced. Temperatures as high as 3,000° C. were measured. The spectra show almost as many lines as are given by the electric arc; while the effects of different temperatures in changing the relative intensity of lines are of high interest when considered in connection with both astronomical and physical problems. The effect of different gases in the furnace, also of high pressures and the observation of absorption phenomena, offer each a large field of work which has not yet been taken up.

During April an electric furnace of the Moissan type, inclosed in an air-tight chamber, was set up and has been used by Dr. OLMSTED for the investigation of the spectra of hydrides, to be used for comparison with solar spectra in the identification of unknown lines, especially of the flutings obtained in the spectra of sun-spots. Good results for the spectra of magnesium and calcium hydrides are being obtained.

The recent discovery of the separation of lines in sun-spots, indicating the presence of magnetic fields on the Sun, has led to a supplementary laboratory investigation of the Zeeman effect, the large Du Bois electro-magnet being arranged so that an electric spark between the poles may be photographed either parallel to the lines of magnetic force or at an angle to them. The magnet gives a field strength up to 36,000 c. g. s. units. Photographs are being obtained of the spectra of iron and other substances, giving an excellent separation of the spectrum lines for magnetic fields of known strength, allowing a detailed comparison with the separations obtained in the solar photographs.

Most of the laboratory investigations cover the whole range of the visible spectrum, requiring the use of photographic plates sensitive to red light in addition to those commercially obtainable. The laboratory dark-room is fitted up for the

sensitizing of plates for the red region, which are thus used while perfectly fresh and are handled with the same facility as the ordinary plates.

The comparison of intensities of lines on photographic plates has been carried on by Miss WICKHAM of the computing division through the use of the Zeiss spectrocomparator, adapted so as to show a portion of the spectrum under examination and a specially prepared photographic scale in the field of view at the same time, giving a definite value to the intensity of each spectrum line and allowing an accurate comparison of the intensities of lines in different spectra.

COMPUTING DIVISION.

Some of the results obtained in the computing division, under the direction of Mr. ADAMS, have already been given. The heliomicrometer has been used by Miss WARE for all measurements of the positions of flocculi. The rapidity of measurement has been greatly increased by ruling one hemisphere of the globe with meridians and parallels 1° apart. The position of the cross-hairs, after they have been set on a flocculus, is estimated to tenths of a degree. The precision of measurement proves to be amply sufficient; in fact, the latitudes and longitudes are almost as precise as those obtained with the aid of the circles.

The measurement of the areas covered by the calcium flocculi, to serve as an index of the solar activity, has been continued throughout the year. This work has been carried on by Miss SMITH with the aid of the special photometer devised for this purpose and referred to in the report of last year. The method of reduction which has been followed is the same as that previously described and the results obtained have proved to be fully as satisfactory as the character of the objects measured would seem to warrant. The values obtained for a period of about seven months have been platted and indicate very clearly the variation in the areas covered by the flocculi as the spot-groups pass across the surface of the Sun. The time interval is of course too short to give any indication of the eleven-year period, but there is every reason to suppose that these determinations will furnish an excellent measure of the Sun's activity.

The measurement of the plates used in the determination of the rotation of the Sun has been done for the most part by Miss LASBY, and in addition she has devoted considerable time to the measurement of the displacements found in the spectra of the center and limb of the Sun. The extension of the rotation work to include the lines of hydrogen and the line of calcium at λ 4227 has increased considerably the amount of measurement which it has been necessary to do in carrying out this research.

The definitive reduction of our plates of the sun-spot spectrum, and the identification of the unknown lines which appear on them, has involved a great amount of measurement and reduction. This work has been carried on for the most part by Miss BURWELL and Miss WICKHAM. Miss BURWELL has determined the wave-lengths of the sun-spot lines, and Miss WICKHAM has measured, for purposes of identification, plates of the titanium-oxide flutings obtained in the laboratory. Some idea of the amount of labor involved may be obtained from the fact that in the extent of spectrum between λ 5000 and λ 5500 there occur over 1,500 lines, whose wave-lengths in the spot spectrum must be determined and for which suitable identifications with laboratory spectra have to be found.

In addition to her work on the measurement of the titanium-oxide flutings, Miss WICKHAM has devoted much time to the estimation of the intensities of the lines upon the plates of furnace spectra obtained by Dr. KING.

CONSTRUCTION DIVISION.

The construction division, under the superintendence of Professor RITCHEY, has been occupied during the year with the erection on Mount Wilson of the steel building and dome for the 60-inch reflector; the completion of this instrument, its transportation to the mountain and its erection in the dome; the erection and equipment of the new spectroscopic laboratory in Pasadena; the construction of a spectroheliograph of thirty feet focal length and a grinding-machine for the 100-inch Hooker mirror; the completion of the Mount Wilson road; and other miscellaneous work.

The instrument and optical shops were closely occupied with the 60-inch reflector during the entire year. The optical work included the grinding and figuring of the two plane and two hyperboloidal mirrors, which were tested in combination with the 60-inch mirror. In the instrument shop the mounting was completed and erected, so that the operation of all parts of the mechanism could be thoroughly tested before they were sent to the mountain. In the tests the various quick and slow motions, effected by electric motors, worked perfectly, and the mounting showed no evidence of flexure.

The experience of the previous year had shown the necessity of widening some sections of the Mount Wilson road, in order to permit the large and heavy parts of the mounting to be carried safely on the automobile truck. This work was done in the spring, immediately after the close of the rainy season. At the same time the erection of the steel building and dome was resumed. During June and July the mounting was taken to the summit without difficulty on the truck, though four strong mules were needed to assist the engine in hauling the heaviest loads, weighing five tons, over the steep grades. The most troublesome load was the large steel telescope-tube, 6.5 feet in diameter and 18 feet long, which was taken up as a single piece. All parts of the telescope, including the 60-inch mirror, reached the summit without the slightest injury. Work on the dome and building was completed early in September, and the telescope was ready for use in December. It is now yielding excellent photographs of nebulæ and other objects.

A spectroheliograph of thirty feet focal length, designed for use with the tower telescope, has been completed and is now in use. The great linear dispersion of this instrument, and the fact that it will permit three photographs of the same region of the Sun to be taken simultaneously with the light of three different lines, should prove advantageous in certain new fields of solar research. The dispersing member of this spectroheliograph is a large fluid prism, with circular faces twelve inches in diameter, which is twice traversed by the light (Littrow arrangement).

A 100-inch disk for the Hooker telescope mirror has been received from the St. Gobain plate-glass works, but it is not sufficiently homogeneous, and another one will be cast.

George E. Hale, *Director.*

STUDENTS' OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

The work of the Berkeley Astronomical Department during the last year has been confined almost entirely to instruction. The enrollment for the year exceeds the five hundred mark. No additions have been made to the teaching force. Several courses that are usually given could not be given this year, due to the absence of the Director, Professor A. O. LEUSCHNER, who has been abroad since July on his sabbatical leave. Because of his absence no work has been done upon the Watson asteroids.

A short but excellent series of photographs of Comet Morehouse was obtained in October by Mr. MEYER. The orbit of this comet was computed by Messrs. EINARSSON and MEYER.

The Acting Director, assisted by Mr. MEYER, computed the orbit of *Jupiter's* VIII Satellite by LEUSCHNER's method.

A few micrometer observations of Comet Morehouse have been made. The regular seismological and meteorological observations have been continued during the year. The orbits of Comet Morehouse and *Jupiter's* VIII Satellite have been published in the *Lick Observatory Bulletin.*

A few additions have been made to the equipment of the observatory, among which are: 1. A new position micrometer for the 6-inch telescope, made by GAERTNER of Chicago (the old micrometer has been adapted for use on the 5-inch telescope; 2. A small spectrometer for student use; 3. An induction coil; 4. A storage battery.

In September Director LEUSCHNER attended the Versammlung der Astronomischen Gesellschaft at Vienna, when he presented an outline of his new analytical method for determining the orbits of new satellites. His paper is entitled "Versuch einer Bahnbestimmung mit sofortiger Berücksichtigung der Störungen." It has been published in the *Vierteljahrsschrift der Astronomischen Gesellschaft.*

R. T. CRAWFORD, *Acting Director.*

GENERAL NOTES.

A Bright Meteor.—Dr. G. K. GILBERT, of the U. S. Geological Survey, has sent a memorandum of a bright meteor seen by him at 9:40 P. M. on April 4, 1909, at Berkeley, California. From a sketch furnished by the observer it is shown that the meteor appeared some ten degrees below *Alioth* (*ε Ursæ Majoris*), moved downward and toward the west, disappearing behind the Berkeley hills some distance west of Grizzly Peak, at a point which would make nearly an equilateral triangle with *Alioth* and *Polaris*. This point was probably very close to the head of the *Dragon*. Dr. GILBERT's notes concerning the meteor are as follows: "Seen from campus, near athletic field, Berkeley, California. Motion slow. Meteor increased in brilliancy as it descended and also divided so as to make a cluster. Train distinct but much less persistent than those of the *Perseids*. Train yellower than the meteor. Diameter of cluster before disappearing behind hills about one tenth of Moon. A meteor as bright as *Venus* was seen the previous evening."

Compendium of Variable Stars.—At the last meeting of the Astronomische Gesellschaft Rev. Father J. G .HAGEN, S. J., announced the preparation, in collaboration with Dr. STEIN, of a book on variable stars, under the title, "Ein Lehrbuch der veränderlichen Sterne." The book is to consist of two parts, a technical part to be prepared by Mr. HAGEN and a theoretical part to be prepared by Mr. STEIN.

The technical part is to be treated under three heads—statistics, methods of observing, and methods of reduction,—and each of these is to be treated under several sub-heads. The theoretical part is to be devoted to the several theories which have been advanced to explain the phenomena of variable stars. These are to be treated under two general heads—first, those referring to single stars, and, second, those referring to double or multiple stars.

The above information is taken from a rather elaborate outline of the contents of the proposed book given in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, **43**, part 4. This book will, we feel sure, be of great interest to variable

star workers, and the reputations of the authors guarantee that the work will be executed with great care and scientific accuracy. S. D. T.

Notes from "Science."—Professor H. G. VAN DE SANDE BAKHUYZEN has retired from the directorship of the Leyden Observatory and is succeeded by Mr. E. F. VAN DE SANDE BAKHUYZEN.

Dr. MAX WOLF has been appointed director of the observatory at Heidelberg in succession to Dr. WILHELM VALENTINER, who has retired owing to ill health.

Dr. HERMANN KOBOLD has been called from Kiel, to a professorship of astronomy at Berlin.

Professor GEORGE E. HALE, director of the Mount Wilson Solar Observatory, has been elected a foreign member of the Royal Society.

A geodetic survey department for Canada has been established under Dr. W. F. KING, chief astronomer of the Dominion.

National Academy.—At the annual meeting of the National Academy of Sciences held in Washington during the latter part of April two papers upon astronomical subjects were presented: "The Nature and Possible Origin of the Milky Way," by G. C. COMSTOCK; and "Determinations of Stellar Parallax from Photographs Made by ARTHUR R. HINKS and the Writer," by H. N. RUSSEL (introduced by G. C. COMSTOCK). An abstract of Professor COMSTOCK's paper has been printed in the number of *Science* issued on May 21st.

Four California astronomers took part in the Astrographic Chart Conference at Paris, April 19th,—Professors HALE, LEUSCHNER, PERRINE, and RITCHEY.

There is an interesting article in the May number of *Observatory*, by Professor WHITTAKER, Astronomer Royal of Ireland, on "The Professional Training of Astronomers." The article was intended to be suggestive to university students of astronomy and their teachers, but will also interest amateurs who desire to equip themselves for astronomical study. The periodical is in the Society library.

NEW PUBLICATIONS.

ALLESIO, ALBERTO. Determinazione della gravita relativa fra Padova e Potsdam. Genova. 1908. 4to. 148 pp. Paper.

Annalen der Kaiserlichen Universitäts-Sternwarte in Strassburg. Beobachtungen von Nebelflecken und Trabanten. Karlsruhe. 1909. Folio. 385 pp. Paper.

Annual report of the director Kodaikánal and Madras observatories for 1908. Madras. 1909. Folio. 26 pp. Paper.

BLOCK, HENRIK. Sur les chocs dans le problème des trois corps. Uppsala and Stockholm. 1908. 8to. 32 pp. Paper.

BOCCARDI, GIOVANNI. Osservazioni di ascensioni sette eseguite nel R. Osservatorio di Torino negli anni 1904-06. Torino. 1908. Folio. 118 pp. Paper.

CHARLIER, C. V. L. Das Planetarische Rotationsproblem. Uppsala und Stockholm. 1908. 8to. 14 pp. Paper.

LEON, LUIS G. Observaciones solares. Mexico. 1909. Folio. Paper.

Durante el mes de diciembre de 1908. 4 pp.
Durante el mes de enero de 1909. 5 pp.

MACMILLAN, WILLIAM D. On the loss of energy by friction of the tides. Extracted from Publication 107 of the Carnegie Institution of Washington, pp. 69-75. 8to. 67 pp. Paper.

Mitteilungen der Grossh. Sternwarte zu Heidelberg. XIV. Der persönlicher Fehler bei der Beobachtung von Sternbedeckungen. Von E. PRZYBYLLOK. Karlsruhe. 1909. 8to. 27 pp. Paper.

MOULTON, FOREST RAY. On certain relations among the possible changes in the motions of mutually attracting spheres when disturbed by tidal interactions and notes on the possibility of fission of a contracting rotating fluid mass. Extracted from Publication 107 of the Carnegie Institution of Washington, pp. 77-133 and 135-160. 4to. 25 pp. Paper.

Results of observations made at the Coast and Geodetic Survey magnetic observatories. DANIEL L. HAZARD. Washington. 1909. Folio. Paper.
At Baldwin, Kansas, 1901-1904. 138 pp.
At Chentenham, Maryland, 1901-1904. 206 pp.
At Vieques, Porto Rico, 1903-1904. 70 pp.
At Sitka, Alaska, 1902-1904. 129 pp.
Near Honolulu, Hawaii, 1902-1904. 130 pp.

SCHIAPARELLI, GIOVANNI. Orbite cometarie, correnti cosmiche, meteoriti. Estratta dalla Rivista di Fisica, Matematica e Scienze Naturali (Pavia). Pavia. 1908. 8to. 27 pp. Paper.

SMILLIE, THOMAS W. Recent progress in color photography. From the Smithsonian report for 1907, pp. 231-237. Washington. 1908. 8to. 6 pp. Paper.

Veröffentlichungen der Grossh. Sternwarte zu Heidelberg. Mikrometrische Messungen von Doppelsternen. Von E. PRZYBYLLOK. Karlsruhe. 1908. 4to. 91 pp. Paper.

Verslag van den Staat der Stenewacht te Leiden en van de Aldaar volbrachte Waaremingen, van 18 September 1906 tof 21 September 1908. H. G. VAN DE SANDE BAKHUYZEN. Leiden. 1909. 8to. 31 pp. Paper.

WILLIAMS, A. STANLEY. Zenographical fragments II. The motions and changes of the markings on *Jupiter* in 1888. London. 1909. 8to. 104 pp. Paper.

ZAPP, ERNST. Untersuchung eines speziellen Falles des Drei— und Vierkörperproblems. Inaugural-dissertation. München. 1908. 84 pp. Paper.

AMENDMENT TO BY-LAWS.

At the annual meeting of the Board of Directors of the Astronomical Society of the Pacific, held in San Francisco on March 27, 1909, a report was presented by the Committee on Publication recommending an amendment to the By-Laws as follows:—

We recommend that the second paragraph of article IX of the By-Laws be amended to read as follows:—

"A meeting shall be held in the Library of the Lick Observatory at a suitable hour on the last Saturday of August; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M. on the last Saturdays of January, March, June and November, but it shall be within the discretion of the President to designate other places of meeting, in San Francisco or vicinity, for the meetings of January, June and November, whenever, in his opinion, such change will be to the advantage of the Society."

It was the unanimous opinion of the six Directors present—viz., Messrs. BURCKHALTER, HALE, GALLOWAY, CUSHING, MOLERA, and CRAWFORD—that the By-Laws should be amended as recommended by the committee, and the Secretary was instructed to obtain the written consent of at least three other Directors, which has now been done through Directors CAMPBELL, AITKEN, and RICHARDSON.

D. S. RICHARDSON, *Secretary.*

OFFICERS OF THE SOCIETY.

Mr. W. W. Campbell...*President*
Mr. G. E. Hale...*First Vice-President*
Mr. F. Morse...*Second Vice-President*
Mr. E. J. Molera...*Third Vice-President*
Mr. D. S. Richardson...*Secretary and Treasurer*
Mr. R. G. Aitken (Mount Hamilton, Cal.)...*Secretary*

Board of Directors—Messrs. Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Molera, Richardson.

Finance Committee—Messrs. Molera, Crocker, Cushing.

Committee on Publication—Messrs. Townley, Maddrill, Curtis.

Library Committee—Messrs. Crawford, Townley, Einarsson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Townley, Curtis.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

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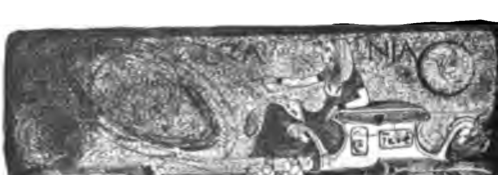


SIMON NEWCOMB.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XXI. San Francisco, California, October 10, 1909. No. 128

SIMON NEWCOMB.

By R. G. Aitken.

That by the death of Simon Newcomb on the 11th of July, 1909, America lost her foremost astronomer, if not her foremost man of science, is universally acknowledged. We may, indeed, say with confidence that Professor Newcomb, for the past thirty years, ranked as one of the two or three greatest astronomers, not only of America, but of the world. It is a matter of satisfaction to recall that our Society brought this fact into prominence more than ten years ago.

In the autumn of 1897 letters were addressed by our secretary to the directors of the Berlin, Greenwich, and Paris observatories in Europe, and of the Harvard, Lick, and Yerkes observatories in this country, asking them to assist us in carrying out the statutes for the award of the Bruce Medal by nominating not more than three persons each who, in their judgment, were entitled to receive the medal[1] "for distinguished services to astronomy."

The statutes for the award of this medal, wisely adopted by Miss Bruce at Professor Holden's suggestion, provide that the medal can be awarded by the Directors of our Society only to persons thus nominated by the heads of six of the great observatories of the world, and I think I am betraying no confidence when I say that the Directors of the Society, so far, have conferred the medal upon that astronomer whose name was most prominent on these nominating lists.

Therefore, as Mr. William Alvord, President of the Society, in his address on awarding the first Bruce Medal, said, " . . . it will be perfectly clear that the recipient must have endeared himself, in a scientific sense, to the astronomers of

[1] For the year 1898, the first award.

the world." I cannot do better than to quote further from this address: "Not only will this also be true of each subsequent bestowal of the medal, but such a condition must especially mark this first presentation, since, according to the desires of Miss BRUCE, the medal is to be 'international in character, and may be awarded to citizens of any country and to persons of either sex.' It must strike us, then, with peculiar force that of all the names of living astronomers that have been so brilliantly connected with the wonderful advances in astronomical research during the past half-century, with all the manifold branches of observational work, mathematical investigation, spectroscopic and photographic study, in which to seek out a worthy exponent for this distinction, one name stood forward so prominently in the communications from heads of six leading observatories of the world, that the Directors of this Society could but set the seal of their approval upon the verdict of his peers, and award the first Bruce Medal to SIMON NEWCOMB."

It is not my purpose to write a formal sketch of Professor NEWCOMB's life. The salient features of his career may be gathered from any one of the numerous notices that have been printed since his death, or from the address[1] from which I have just quoted. And any readers who desire a more complete account than these articles provide cannot do better than to read his "Reminiscences of an Astronomer," in which he has given us not only an excellent autobiography but also many interesting sidelights on the history of astronomy in this country.

I do, however, desire to dwell upon certain features of his career that seem to me worthy to be strongly emphasized, particularly the great services he rendered to astronomy outside of his technical contributions and researches, and, in this connection, to bring again to your attention the important relation in which he stood to the Lick Observatory in its early history.

It was in the summer of 1874 that Mr. D. O. MILLS, President of the first Board of Lick Trustees, visited Washington to consult with the astronomers there, especially Professor NEWCOMB, concerning the proposed Lick telescope. As

[1] See these *Publications*, **10**, 49, 1898.

always in such matters, NEWCOMB took the greatest interest in this new foundation, and gave the best advice in his power. Among other things, he suggested at that time that Professor HOLDEN would be well qualified to serve as director, and we have the authority of both men for saying that sketches of the plans of the observatory were drawn by them in that year. The plans finally adopted did not differ in material points from these early sketches.

In 1875, Professor NEWCOMB visited Europe for the Lick trustees "with a view of determining whether there was any chance of getting the telescope made abroad."

The report was not very encouraging, and when Mr. LICK'S death left the third Board of Trustees free to act as they deemed best, the contract for the lenses was awarded, as is known, to the CLARKS. It is certain that NEWCOMB strongly favored this, and also that his advice weighed heavily in the decision to build a refracting telescope rather than a reflector. In 1876 Captain FLOYD, chairman of the third Board of Trustees, visited him; in 1879 FLOYD and FRASER, superintendent of construction of the observatory, consulted him in Washington; in September of that year he spent several days on Mount Hamilton, while BURNHAM was engaged, at the recommendation of both NEWCOMB and HOLDEN, in testing the atmospheric conditions there. It was in the autumn of the same year that the preliminary plans for the building were drawn at Washington under the joint direction of these two astronomers in NEWCOMB'S office. In 1885 he was again consulted, this time "on the question of choosing Professor HOLDEN as president of the University" of California; and in 1887 he was invited to go with Captain FLOYD to Cleveland "to inspect the telescope, which was now nearly ready for delivery."

I think it is clear from these facts that Professor NEWCOMB'S advice and recommendations were most potent factors in shaping the policy of the Lick Trustees, not only in the matter of buildings and equipment, but in the far more important matter of selecting the man who was to plan and direct the scientific work of the new observatory. To the close of his life Professor NEWCOMB continued to take the keenest interest in the work of the Lick Observatory, and stood ready at all times to aid its successive directors in every way in his power.

This little history furnishes an excellent example of what I mean by the influence Professor Newcomb exerted upon the progress of astronomy in this country during the half-century of his active career.

His official position, his eminence as an investigator, his practicality and sound common sense, and his forceful personality combined to give to all of his opinions the greatest weight. He was of course very influential in securing the powerful equipment of the Naval Observatory, and he was one of the chief advisers to the National Government in the development of several of the scientific bureaus at Washington. It is well known, also, that he was freely consulted by the astronomers of this country not only, but by those of Europe as well, on many of the important projects that have advanced our science during his lifetime.

Now we find him one of the leading members of the international committee which, at Paris in 1896, adopted a uniform system of constants for use in the nautical almanacs and ephemerides of the world; again, as leader of the astronomical congress held in connection with the dedication of the Yerkes Observatory; then as first president (re-elected as long as he would serve) of the Astronomical and Astrophysical Society of America; as president of the International Congress of Arts and Sciences at St. Louis in 1904;—the list could be made almost as long as the list of his scientific memoirs or as that of the honorary degrees, medals, and other distinctions conferred upon him. In all of these capacities his qualities of leadership were strongly exerted to stimulate the broadest possible development of the science to which he was devoted and particularly to encourage the growth of that spirit of co-operation in large programs of work that now characterizes astronomy.

Nor was he less interested in promoting the work of individual astronomers of whose ability he was convinced, a fact to which several of the recently published notices of his life bear witness.

While thus doing what he could to advance the science of astronomy professionally, Professor Newcomb also realized the desirability of popularizing, in the best sense of the word, the advances of our knowledge of the universe. Too often it

happens that the scientific investigator considers it beneath his dignity to write a popular article. In many other cases the able student is not qualified to present the results of his work in non-technical language. But NEWCOMB added to the power of clear thinking the faculty of lucid expression, and he cheerfully devoted these powers to the task of writing books and magazine articles in which the latest results of astronomical research were made clearly intelligible and even fascinating to the general reader. Through these writings and his numerous lectures and addresses he exerted an influence on the progress of astronomy that is incalculable. When one considers the enormous amount of labor involved in the extensive technical investigations which he conducted, one must wonder how he found time for all of these additional activities. It is obvious that he could only do so because, in addition to his genius as a mathematician and astronomer, he possessed in an unusual degree the power of continuous work.

As a general rule a man who would carry a great piece of research work to completion must take as his motto, "This one thing I do," and must decline to undertake any other serious duties. So far as his professional labors were concerned, Professor NEWCOMB, too, adopted this motto, at least in spirit, for he steadfastly refused to be turned away from the life task he had chosen by any offer, however tempting, of work in other lines.

It is not necessary at this time to review this great work, which amounted practically to a complete revision and rediscussion of all the data of gravitational astronomy. It has been dealt with in part in the Bruce Medal address, already quoted, and more fully in a recent article in *Science*[1] by Dr. G. W. HILL, who was Professor NEWCOMB's associate in a considerable part of it, and who of all living men is perhaps best fitted to estimate its importance.

It is a pleasure to think that Professor NEWCOMB had the satisfaction of rounding out his work by the completion of his final memoir on the Moon's motion. His unfaltering loyalty and indomitable will and courage kept him at his work to the closing hours of his life, and only a few weeks before the end came the final pages were written.

[1] *Science*, **30**, 353, (Sept. 17, 1909).

It is gratifying, too, to think that, so far at least as the scientific world is concerned, his great services were adequately recognized and honored during his lifetime.

September, 1909.

THE RETURN OF HALLEY'S COMET.

By W. W. Campbell.

A celestial event of unusual interest is expected soon—the return of Halley's Comet. Its appearance will be welcomed as the coming of a faithful friend, whose visits to the Sun's domains have repeated themselves once every seventy-seven years since long before the time of Christ. Any day may bring the news that this object has been re-discovered, near the northern edge of the constellation *Orion;* but we are really not expecting the announcement until the last third of 1909. The comet will be faint when first seen, for we know quite closely where to look, and the most powerful photographic telescopes in several countries are periodically "prospecting" the critical region.

Why is this comet known as Halley's? The incidents connected with its christening form an interesting chapter in the early history of astronomy. A brilliant comet appeared in 1682, when Halley was a young man, in England. This was Halley's Comet, but his name was not connected with it until much later, as we shall explain. Halley's friend, the great Sir Isaac Newton, had but recently (about 1670-80) discovered the law of gravitation, and had proved that a comet or other body completely subject to the Sun's attraction must move in an ellipse around the Sun. Newton was of a retiring disposition and took no steps to make known his immortal discoveries. Halley, on the contrary, was a man of action. These characteristics of the two men are apparent from their portraits. The manuscript copy of Newton's *Principia* was entrusted to Halley, and the latter, in the absence of other funds available for the purpose, published the book in 1686, at his own expense, though he was a man of small financial

EDMUND HALLEY.

means. This act alone stamps HALLEY as worthy of our homage.

HALLEY realized the wonderful import of The Great Law, certainly as early as 1685, but his opportunity for systematic work in astronomy did not come until 1704, when he was appointed professor of geometry at Oxford. He immediately began the study of comets, basing his studies upon NEWTON'S law. He became the first great calculator of comet orbits. In a little more than a year he had twenty-four to his credit; orbits of all the comets, in fact, for which he could find accurate observations. This meant prodigious labor, in those days, for the good observations and the highly developed methods of our time were unknown. He found that three comets out of the twenty-four had traveled from distant space, around the Sun, and out into distant space, *along the same path,* whereas the other twenty-one had each a different path. Were these three comets one and the same body? If so, their common orbit must be an ellipse. The crude observations of the sixteenth and seventeenth centuries did not permit him to decide whether the orbit was a long ellipse or a parabola (a curve extending out to an infinitely great distance). If the latter, the three comets would have traveled away from our solar system never to return. If they were the same body, they should have returned at about equal intervals of time; and this is what did occur, for the dates when the three comets had been nearest to the Sun were—

1531	August 24	
		Interval, 76.2 years
1607	October 16	
		Interval, 74.9 years
1682	September 4	

The small inequality of intervals he correctly attributed to the disturbing attractions of the planets *Jupiter and Saturn.* He predicted that the great comet would complete another revolution in its orbit in seventy-five or seventy-six years and reappear about 1758. He said that he could not predict the time more accurately, for the effects of *Jupiter's* and *Saturn's* disturbing attractions were not yet computed. HALLEY (born 1656, died 1742) knew that he would not live to witness the return, but he confidently and patriotically called upon posterity to remember that this prediction had been made by an Englishman,—*"ab homine Anglo."*

The comet did return, in March, 1759. It was a little later than expected because of the disturbing attractions of the planets *Uranus* and *Neptune,* which had not yet been discovered, and whose influence upon the comet's orbit, therefore, could not be taken into account. This was indeed a great triumph in exact science, made possible by NEWTON's overwhelming genius and HALLEY's vigor. It is easy to predict the returns of comets in the twentieth century, but this is so because NEWTON and HALLEY lived and labored as pioneers.

Halley's Comet reappeared in 1835, within a few days of the predicted time. It is due to be again "in perihelion," *i. e.,* nearest to the Sun, in the first half of April, 1910. The comet, though invisible, is at present (April, 1909) much closer to us than *Jupiter* is, and slowly drawing nearer to the Sun. When we may expect to see it without telescopic assistance and how bright it will be at maximum are too uncertain for prediction. Certainly for a few months in the first half of 1910 it should be a conspicuous object. Comets brighten and develop their tails as they approach the Sun, reaching their greatest development when in or near perihelion. For this reason it is their unfortunate practice to disappear from view, in the Sun's glare, just when they are largest; and Halley's Comet will be out of sight for a few days while it is passing on the other side of the Sun, probably in March, 1910. We should see it at its best just after perihelion passage.

The history of this most famous of comets prior to HALLEY's first date, 1531, has been traced by three able English astronomers, HIND, COWELL, and CROMMELIN, as far back as B. C. 240. In all, twenty-nine appearances recorded in history have been identified. These have occurred at average intervals of seventy-six and three-quarters years. The individual values of the intervals have varied between seventy-four and a half and seventy-nine years, according as the disturbing actions of the planets combined to shorten or to lengthen the period.

There are extant several quaint pictorial representations at many of its early returns. An especially interesting one, though of minimum scientific value, is for the return in 1066,—the year of William the Conqueror's invasion,—as preserved in the famous Bayeux Tapestry. Sir JOHN HERSCHEL's drawing is probably our best record of its appearance at the 1835

Sir Isaac Newton.

Halley's Comet in 1066, on the Bayeux Tapestry.

return. Fortunately we now have photography to make permanent records of both its general and its detailed structure. The dry-plate puts down details which the eye cannot see, and it does the work with great accuracy. Since BARNARD'S pioneer success in the photography of comets at the Lick Observatory, about 1890, no one seriously attempts to "draw" a comet. An inspection of the two photographs of Comet MOREHOUSE, just visible to the naked eye in the fall of 1908, will show the richness of structural detail, none of which could be seen in any existing telescope.

The long elliptical orbit of Halley's Comet and the nearly circular orbits of the Earth, *Mars, Jupiter, Saturn, Uranus,* and *Neptune* are represented in the figure—approximately to the correct scale; but it should be said that the plane of the comet's orbit makes an angle of 18° with the Earth's orbit plane. The comet's orbit therefore passes "through" the planetary orbits like the two adjacent links of a chain. The comet will approach within fifty-six million miles of the Sun, and then recede during thirty-eight years until it is far beyond *Neptune's* path. In perihelion it must travel thirty-four miles per second, but at the outer turning its speed will be less than one mile a second.

For purposes of description, it has been found convenient to divide the structure of a comet into three parts, as follows:—

1. The densest and brightest part near the center of the head, called the *nucleus*. Nearly all the mass of a typical comet resides in the nucleus.

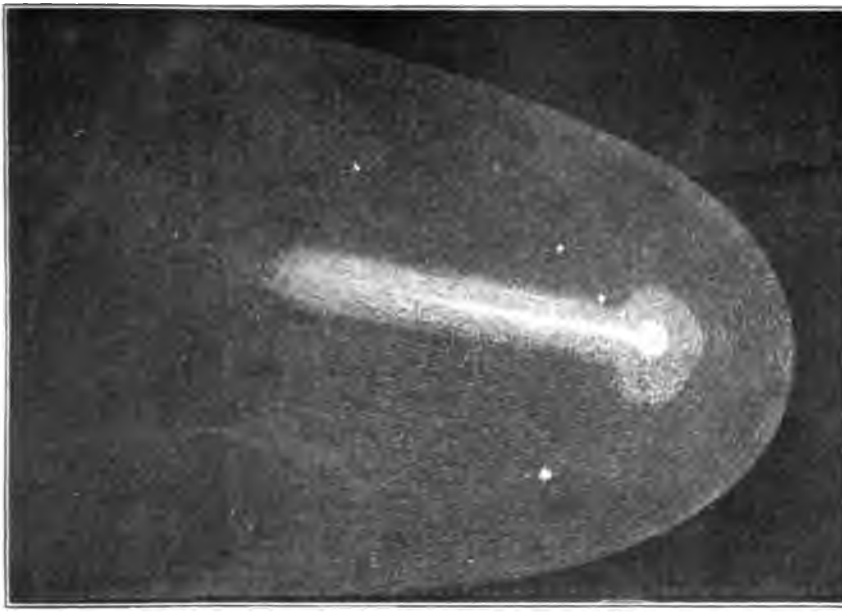
2. The *coma*, or envelope of low density surrounding the nucleus. In occasional comets the head consists entirely of coma without an apparent nucleus.

3. The *tail*, which always points approximately away from the Sun. When the comet is traveling toward the Sun the tail follows the head; when the comet is going away from the Sun, the tail precedes the head. This is illustrated in the drawing of the comet's orbit.

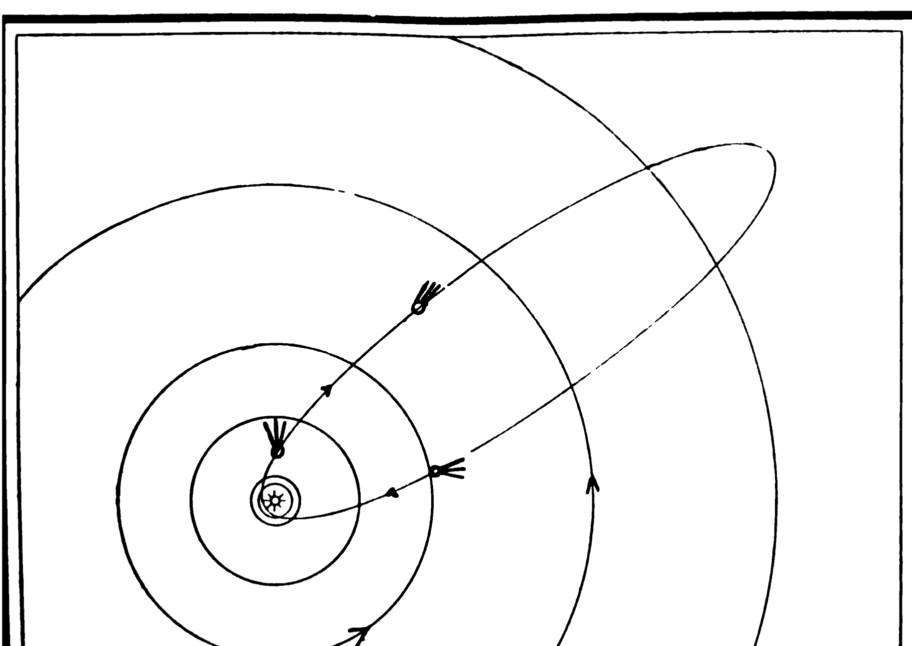
The fact that a comet's tail always points away from the Sun was early recognized. There could be no doubt that some force originating in the Sun was repellant to the materials composing the tail; but to determine the nature of this force defied us for generations.

Since the coming of photography and the accurate recording of details of comet structure utterly invisible to the eye, it has been possible to measure these motions. Comparisons of photographs of the same comet made two or three hours apart have shown that condensations and other structural forms have moved rapidly outward during the interval; only a few miles per second at first, but faster and faster as the distance out in the tail increased. Some observed speeds have been nearly fifty miles per second. Fifty miles per second is more than four million miles per day. If such motions exist, the constituents of the tail on one night are not the constituents of the tail of the following nights. Photographs of many comets taken on certain nights seem to bear no resemblance to those taken on the preceding or following night. The tails of the earlier dates have been driven off into space, scattered into invisibility, and entirely new tails have taken their places. The forces acting outwardly from the Sun and responsible for these expulsions were mysterious, and it is only within the last ten years that a fairly satisfactory theory has been established. Half a century ago the great physicist, CLERK-MAXWELL, in developing the electro-magnetic theory of light, deduced mathematically that the so-called light- and heat-waves, in striking upon any object, exert a pressure upon that object, very much as ocean waves falling upon the cliffs press against the obstructing rocks. The pressure due to light- and heat-waves, called radiation pressure, is extremely slight; so slight, in fact, that skilled experimenters were unable to detect its existence for many years. At last, about the year 1900, a Russian physicist, LEBEDEW, was able to observe this effect; and a few months later two American physicists, NICHOLS and HULL, were even more successful, for their accurate observations showed a satisfactory agreement with the demands of MAXWELL's theory.

Almost immediately the famous Swedish scientist, ARRHENIUS, expressed his belief that in this pressure of the Sun's heat- and light-waves we have the force which forms comets' tails. All the materials of a comet are necessarily attracted by the Sun, according to the law of gravitation. There can be no doubt that they are also acted upon by radiation pressure. The former seeks to draw all into the Sun, the latter to



Halley's Comet in 1835.
(By Sir John Herschel.)



Orbits of the Planets and the Comet.
(The smallest circle is the Earth's orbit.)

drive them into outer space. These are opposing forces. On the more massive parts of a comet, comprising the nucleus, radiation pressure is ineffective; and the nucleus moves along in its prescribed curve with remarkable precision. Not so with the finely divided materials of the coma and tail. Gravity acts as a function of a particle's mass, whereas radiation pressure's action is dependent upon the surface-area of a particle in relation to its mass. As particles become smaller and smaller a size will be reached such that these opposing forces will be precisely balanced. Particles larger than these will be drawn nearer to the Sun. Particles smaller will recede from the Sun.

What seems to take place in a comet is something like this: Minute particles of solid matter or molecules of gas are expelled from the nucleus chiefly on the side toward the Sun, probably under the influence of the Sun's heat. Radiation pressure acts upon these particles to turn them directly away from the Sun; and the cloud of particles thus projected forms the tail. As the repellant forces act continuously, the particles must travel continuously faster; and this is the observed fact. Smaller and less dense particles must travel more rapidly than the larger and denser ones.

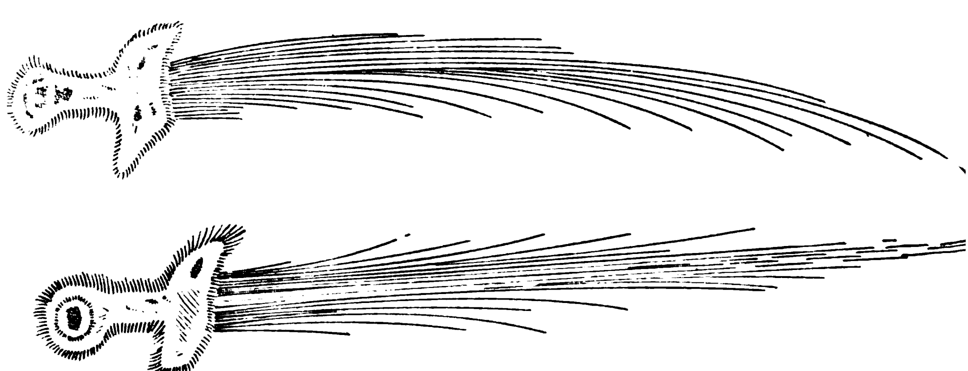
The constant expulsion of matter along the tail into outer space must of necessity cause a comet to grow smaller. Disintegration is continuous, and the tail at any moment is made up of materials lost forever from the nucleus. Several faint comets moving around the Sun in small orbits have been observed to be fainter at each successive return. Some have even disappeared entirely. Two such comets, now lost to view, reveal themselves only by virtue of meteor showers about the middle of August and the middle of November: the matter composing their nuclei has been scattered along their orbits, and the annual passing of the Earth across these orbits leads to collisions between the cometary fragments and our higher atmosphere. There is no reason to doubt that Halley's Comet is slowly disintegrating, and, after long ages, will suffer some such fate.

Our knowledge of the chemical composition of comets and of the state in which cometary matter exists is meager and unsatisfactory. A few give spectra very like that of our own Sun, indicating that they are shining by reflected sunlight, as the

planets shine. Other comets send out their own light, almost exclusively, the radiations coming chiefly from carbon and cyanogen sources. Still others have mixed spectra, showing both inherent light and reflected light. Why comets shine by virtue of light within themselves is a mystery, for it is difficult to conceive that such attenuated bodies should have the heat of incandescence throughout their mass. Although many comets have volumes thousands of times as great as the Sun's volume, their total mass is insignificant even in comparison with that of the Earth; and such mass as they have is nearly all in the nucleus. The tails are surely less dense than the most perfect vacuum we can produce in the laboratory.

Halley's Comet is due to pass near the Earth in May, 1910,—perhaps within 10,000,000 miles of us. Let no one draw the inference that there may be a dangerous collision with the Earth, for such is not the case. Their paths are too widely separated. Even if the path of the comet were entirely unknown, we could say that the chance of a collision with the denser nucleus is so small as not to call for consideration. And if we should pass through the tail, there would be no evidence of such an encounter, unless it consist of a harmless meteor shower, for the tails of comets are certainly composed of exceedingly minute and widely scattered particles.

The ancients thought of comets as hairy objects, from the appearance of the tails; hence the origin of the term "comet," from the Greek *kometes,* signifying "long-haired." This belief prevailed certainly up to HALLEY's day and generation.



REPRESENTATIONS OF COMETS AS FLAMING SWORDS.

Comet Morehouse, Photographed at Lick Observatory, November 15, 1908.

Comet Morehouse, Photographed at Lick Observatory, November 18, 1908.

All sorts of fantastic and fearsome ideas have attached to comets, from early historical times to near the close of the nineteenth century. The writer remembers clearly that his neighbors of thirty years ago considered comets to be messengers of disaster. The greatest comet of the nineteenth century, DONATI's of 1858, was the accredited forerunner of our Civil War. Medieval representations of comets as flaming swords were common.

In HOMER's "Iliad" XIX, 381, we read:—

> "Like the red star, that from his flaming hair
> Shakes down disease, pestilence and war."

From EVELYN's Diary of 1624:—

> " . . . the effect of that comet, 1618, still working in the prodigious revolutions now beginning in Europe, especially in Germany."

From MILTON's "Paradise Lost," II, 708-711:—

> " . . . and like a comet burn'd,
> That fires the length of Ophiuchus huge
> In th' Arctic sky, and from his horrid hair
> Shakes pestilence and war."

Not the least of the services of science to civilization has been the gradual emancipation of humanity from all fear of comets.

Astronomers will welcome the coming of Halley's Comet, full of hope that the photo-dry-plate, the spectroscope, and other ways and means of attack invented since its last visit in 1835 will enable them to remove something of the mystery of comets, the most mysterious of all celestial bodies.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1909.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	Nov. 4,	$1^h\ 38^m$ P.M.	Last Quarter..	Dec. 4,	$8^h\ 12^m$ A.M.
Full Moon ...	" 12,	6 18 P.M.	Full Moon	" 12,	11 59 A.M.
First Quarter..	" 20,	9 29 A.M.	First Quarter..	" 19,	6 18 P.M.
New Moon ...	" 27,	12 51 A.M.	New Moon ...	" 26,	1 30 P.M.

There will be a total eclipse of the Moon on the night of November 26th-27th. The entire eclipse will be visible through-

out the United States. The principal events of the eclipse occur as follows, Pacific time:—

Moon enters shadow	Nov. 26	11^h	11^m	P.M.
Total eclipse begins	" 27	12	14	A.M.
Middle of the eclipse	" 27	12	55	A.M.
Total eclipse ends	" 27	1	36	A.M.
Moon leaves shadow	" 27	2	38	A.M.

There will be a partial eclipse of the Sun on the afternoon of December 12th. No part of the eclipse will be visible in the United States, as the eclipse track is confined to the region near the South Pole. Southern Australia, New Zealand, and Tasmania will have a few minutes of partial eclipse.

The Sun reaches the winter solstice, its greatest distance south, December 22d, 3 A.M., Pacific time.

The Earth is in perihelion just after the close of the year on January 1st, 3 A.M., Pacific time.

Mercury on November 1st has just passed greatest west elongation, and is a morning star, rising about an hour and a half before sunrise, and the interval remains as great as an hour until near the middle of the month. It will be in good position for observation in the morning twilight for the first ten days of November. It passes superior conjunction and becomes an evening star on December 2d. By the end of the month it has moved far enough away from the Sun so that it can be seen in the evening twilight, and on December 31st it sets about an hour and a quarter after sunset.

Venus is an evening star, setting on November 1st about two and a quarter hours after sunset. This interval increases rapidly, and by the end of December it is more than three and one half hours. The planet reaches its greatest east elongation on December 2d, and its apparent distance from the Sun is then 47° 18′. It moves 62° eastward and 11° northward through *Sagittarius* and *Capricorn*. Toward the close of December it will have attained nearly its maximum brightness, and may be seen in the full daylight with the naked eye.

Mars is still in fine position for observation, not setting until nearly 3 A.M. on November 1st and nearly 1 A.M. on December 31st. It again took up its eastward motion at the end of October, and during November and December will move 19° eastward and 11° northward in the constellation *Pisces*. By

December 14th it will have reached the line at which it began its westward motion on August 23d, but it will be about 6° north of its August position. Its distance from the Earth in millions of miles increases from 49 on November 1st to 92 on December 31st, being on that date distant from us just a little less than the Earth's mean distance from the Sun. On November 1st its brightness is only a little more than half of its opposition brightness, and it will lose light rapidly, so that on December 31st it will be only one fourth as bright as it was on November 1st and only about one ninth as bright as it was at opposition. It will, however, still be conspicuous. Throughout the period *Mars* and *Saturn* will be in the same quarter of the heavens. On November 1st *Saturn* will be about 21° east of *Mars*. The more rapid motion of *Mars* will cause this distance to diminish to 13° by December 1st, and the two planets will come into conjunction on December 31st, *Mars* passing 3° 12′ north of *Saturn*.

Jupiter rises about 3:30 A.M. on November 1st and at about 12:30 A.M. on December 31st. It moves about 8° eastward and 4° southward in the western part of the constellation *Virgo* toward the first magnitude star *Spica*, *α Virginis*, and at the close of the period is 7° west and 6° north of the star.

Saturn is still in fine position for evening observation, remaining above the horizon until nearly 5 A.M. on November 1st and until after 12:30 A.M. on December 31st. It retrogrades, moves westward, until December 20th not quite 2°, and then moves eastward. It is in the constellation *Pisces*. Its conjunction with *Mars* on December 31st has already been noticed. As seen in the telescope the rings will appear to close up a little toward the end of the year.

Uranus is gradually being overtaken by the *Sun*, but may be seen in the southwestern sky in the evening. It moves about 3° eastward in the constellation *Sagittarius*. No bright star is near, but the planet comes to conjunction with *Venus* on November 23d, the latter being 2° 33′ south, and with *Mercury* on December 28th, the latter being 1° 44′ south.

Neptune is in *Gemini;* rises about 9:30 P.M. on November 1st and at about 5:30 on December 31st.

(SIXTY-SEVENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded in duplicate to Mr. Zaccheus Daniel, of Princeton, New Jersey, for the discovery of an unexpected comet on June 15, 1909, and to M. A. Borrelly, of Marseilles, France, for the discovery of the same comet on June 14, 1909.

It was Mr. Daniel's notice of discovery, with observed position, which was first communicated to the astronomers of this and other countries by cable and telegraph.

W. W. Campbell,
Sidney D. Townley,
Heber D. Curtis,
Committee on the Comet-Medal.

San Francisco, Cal., October 8, 1909.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Recent Progress in the Work of the D. O. Mills Expedition to the Southern Hemisphere.

During the past three years the work on the radial velocity survey of southern stars at the Observatory of the D. O. Mills Expedition has continued to proceed very favorably. At present the total number of plates taken at this station is about two thousand seven hundred. In 1908 Santiago was favored with an exceedingly fine and open winter season, so that it was possible to secure a much better representation than usual for this part of the program; there were about two hundred nights entirely clear in the year May, 1907, to May, 1908, with about sixty other nights of which at least half was available for work. Advices recently received from Santiago indicate that the past winter season has likewise been a very favorable one.

During the past two years most of the work has been done with the two-prism instrument; the limit of this spectrograph, without unduly prolonging exposures, is about photographic magnitude 7.0. At present, however, the program is simply to finish the work on all stars of visual magnitude 5.0 or brighter, leaving the considerable number of available early and solar type stars fainter than the fifth visual magnitude for later investigation.

While the method of refrigeration employed for cooling the mirror and obviating focal changes in the optical system was efficient for the purpose (cf. *Lick Observatory Bulletin,* No. 122), this is no longer used. The seeing for the first two hours after sunset at Santiago is rarely good enough to warrant attempting to gain what slight advantages there are, from the standpoint of spectroscopic work, in having the focus remain constant during this period, though for other classes of work some such method of focal control might be essential. Certain

changes have been made by which it is now possible at all times to test the position of the focus and make the needed changes in the position of the spectrograph in a few seconds. This is made possible by connecting the screws which run the spectrograph up and down by means of bevel gears to a handle close to the observer. Occasionally, in the more unsettled weather conditions of the spring season, the focal length of the optical system will change by an amount too great to be allowed for by the existing amount of travel accorded to the spectrograph, which at present is a little over one inch. For such cases an attachment has been fitted by means of which the observer at the eye end can easily and quickly run the secondary mirror in or out a small distance to compensate for the abnormal change of focus. In the design of future spectrographs for use with large reflecting systems care should be taken to allow for ample travel for the spectrograph in the optical axis, though this attachment for moving the position of the secondary mirror of the Mills Reflector at Santiago works very easily and smoothly. A few other minor improvements have been made in the interests of easier observing; the comparison apparatus has been entirely re-made of steel, with provision for greater ease in adjustment than was allowed for in the former design.

The work of the radial velocity survey has occupied almost the entire time of the two observers, but a number of investigations have been made, or are in progress, along lines more or less allied to the main purpose of the expedition.

Forty-eight spectroscopic binaries have been announced to May, 1909, by Professor W. H. WRIGHT, Dr. H. K. PALMER, Dr. S. ALBRECHT, the writer, and Mr. GEORGE F. PADDOCK. Orbits have been computed by the writer for three of these—*α Carinæ*, *κ Velorum*, and *α Pavonis*. The binary character of perhaps fifteen more stars is suspected, but awaits the confirmation of further plates before being announced.

A number of stars having proper motions of 1″.0 of arc or greater per year have been investigated, mainly with the one-prism instrument; during the course of this work three stars with radial velocities of unusual magnitude have been found:—

Cordoba Zones, 5^h 243	$+242^{km}$	per second
Lacaille 2957	$+100$	" "
Lacaille 8362	-132	" "

Especial interest attaches to the first star on the list, whose proper motion of 8″.7 of arc per year is the greatest hitherto observed. It is believed that the radial velocities of C. Z. 5^h 243 and Lacaille 8362 are the largest observed up to date. KAPTEYN has pointed out that, of stars with considerable proper motion, there is a considerable preponderance of the later stellar types. A number of these stars have not hitherto been observed spectroscopically, and it is of interest to note that thus far in the investigation no case has occurred of a spectrum of the hydrogen or helium type.

During February and March, 1909, considerable time was devoted to securing an extended series of spectrographic and photographic observations of Comet MOREHOUSE.

The one-prism instrument has been employed by Mr. PADDOCK to secure data for the study of several southern variable stars.

Dr. J. H. MOORE arrived in Santiago to take charge of the station on June 5, 1909, and the writer left for California on June 17th, after three and a half years spent in Santiago. It is a pleasure to be able to express here my appreciation of the uniform courtesy and interest manifested by the Government of Chile and by the people of Santiago in the work of the D. O. Mills Expedition. A list of those who have at one time or another thus shown their interest in the expedition is here unnecessary, for I found no department of the government or the municipality of Santiago that was not ready at all times to render any possible assistance. Santiago is a cosmopolitan city of nearly four hundred thousand inhabitants, including about five thousand French, perhaps ten thousand Germans, and a growing colony of about eight hundred English and Americans; there is probably no city south of the equator more pleasant as a place of residence as regards both climatic conditions and social advantages.

HEBER D. CURTIS,
In charge of D. O. Mills Expedition, 1906-09.

ON THE SPECTRUM OF *MARS*.

When the spectrum of *Mars* was under observation extensively at Mount Hamilton in 1894, for the purpose of detecting the presence of water vapor in that planet's atmosphere, I

realized that the water vapor in the Earth's atmosphere was and is the great obstacle in the way of success; and I then resolved to observe the spectrum of *Mars* from the summit of Mount Whitney[1], the highest point of land in the United States, when the planet should again come into a position favorable for the purpose. This would occur in August-September, 1909, when *Mars* would be near the Earth and high above the horizon at the time of year when Mount Whitney could be ascended with instruments.

Late in August, 1908, I ascended Mount Whitney, in order to determine the limiting sizes of instruments which could be transported over the rocky trail on the backs of pack animals, and to plan the living arrangements for the proposed expedition of 1909. I was accompanied by Director C. G. ABBOT, of the Smithsonian Institution Observatory, who was interested in the summit of Mount Whitney in connection with high-altitude studies of solar radiation, as Professor LANGLEY's pioneer expedition had been interested in 1881. We remained on the summit throughout the night of August 24, 1908. The readings of the dry- and wet-bulb thermometers obtained by Director ABBOT indicated that the conditions were extremely favorable for the solution of the proposed problem. Before leaving the summit I decided definitely that observations in 1909, requiring a residence of a week or more, should not be undertaken unless a building of some kind could be erected as a shelter in case of storm; and the question of ways and means was discussed. Director ABBOT suggested that the purposes of such a building might perhaps come within the scope of the Hodgkins Funds of the Smithsonian Institution. A few weeks later, after receiving my description of a building which would meet the needs of the proposed expedition, he was pleased to present the subject to Dr. C. D. WALCOTT, Secretary of the Smithsonian Institution, for consideration. Through the Secretary's lively interest, an appropriation to provide the building for the shelter of the 1909 and any worthy future expeditions was made.

As soon as the shelter was assured, Honorable WILLIAM H. CROCKER, Regent of the University of California, made gen-

[1] In the Sierra Nevada Mountains, California. Longitude, 118° 18′ W.; latitude, +36° 35′; altitude, 4,420 meters (14,501 feet).

erous private provision for all the expenses of the expedition from the Lick Observatory, University of California, including such pieces of new apparatus as were required to complete the equipment. This expedition was on the summit of Mount Whitney from August 28 to September 4, 1909. The instruments consisted of a 16-inch horizontal reflecting telescope and a suitable spectroscope. The observations, made on the nights of September 1st and 2d, were mainly photographic.

The building erected by the Smithsonian Institution, under the supervision of Mr. G. F. MARSH, a public-spirited citizen of Lone Pine, was finished on the morning of our arrival. Its outside dimensions are eleven feet by thirty feet, and it is divided into three rooms. It has walls of stone and cement, doors and roof of steel, and windows of steel and wired-plate glass. No wood or other perishable material was used in its construction. The Crocker Expedition had abundant reason to appreciate the protection afforded by the building, as severe storms were encountered on the summit.

Water vapor in the atmosphere of any planet causes dark bands to be formed at certain definite positions in the spectrum of that planet; conspicuous bands if the water vapor is abundant; inconspicuous bands if the quantity is slight, as this, the only method known, is not a sensitive one.

The observer of *Mars* must look up through the Earth's atmosphere; and the great quantity of water vapor in our atmosphere, if the observer is near sea level or at ordinary altitudes, blots out the effect of any Martian vapor, making a solution of the problem impossible. By ascending Mount Whitney, altitude 14,501 feet, the Crocker Expedition placed itself above probably four-fifths or more of the Earth's water vapor. Further, the air on Mount Whitney was astonishingly dry during the time of the observations. With barometer 17⅔ inches, air temperature 29° Fahrenheit, and wet thermometer 17°, students of the atmosphere will recognize that the observers of *Mars* were looking through remarkably little terrestrial water vapor. Even this small quantity would be almost fatal to success if we did not have a fairly satisfactory method of eliminating its effects, as follows: Our Moon has no appreciable atmosphere. The lunar and Martian spectra will be affected alike by the water vapor in the earth's atmosphere.

These spectra are photographed, one immediately after the other while the conditions in our atmosphere remain unchanged, and with the Moon and *Mars* at the same altitude above the horizon so that their rays traverse equal paths in our atmosphere. If the vapor bands in the Martian spectrum are found to be stronger than in the lunar spectrum, *Mars* has water vapor in considerable quantities. If the bands in the two spectra are estimated to be equally strong, water vapor on *Mars* does not exist in sufficient quantities to be detected by the spectroscopic method. The latter condition was found to exist, when this method was applied under the superlatively favorable conditions existing on Mount Whitney. Both spectra were photographed when *Mars* and the Moon were near the horizon, again when they were at medium altitudes, and finally when they were 49° above the horizon. The best available vapor band, technically called "*a*," was faint in both spectra when the bodies were low, fainter when the bodies were higher, and very faint when the bodies were at their highest; but for equal altitudes the "*a*" bands in the Martian and lunar spectra were equally intense, plainly signifying that the observed bands were due to water vapor in the Earth's atmosphere above the summit of Mount Whitney. This does not mean that *Mars* has no water vapor, but only that the quantity present, if any, must be very slight. Let us recall that we see *Mars* by reflected sunlight. The rays which reached our instruments passed from the Sun into the Martian atmosphere, for the most part down to the surface of the planet, and then out again to us, thus passing twice through the planet's atmosphere and any water vapor it may contain. Even with this multiplying effect on *Mars* the vapor bands in the Martian and lunar spectra were alike, and we conclude that any water vapor in the Martian atmosphere must have been less extensive than was contained in the rarified and remarkably dry air strata above Mount Whitney.

A detailed account of the Crocker Expedition, including descriptions of the spectra as photographed, and a discussion of the results obtained are in press as a *Lick Observatory Bulletin*.

The members of the party were Director W. W. CAMPBELL, Assistant Astronomer SEBASTIAN ALBRECHT, and Carpenter HOOVER, of Lick Observatory; Dr. JOHN J. MILLER, of San

Jose, who took charge of all questions relating to health; and Messrs. G. F. MARSH and W. L. SKINNER, of Lone Pine, California.

W. W. CAMPBELL.

NOTE ON THE MAGNETIC FIELD IN SUN-SPOTS.

In a preliminary note printed in *Publications of the Astronomical Society of the Pacific,* **20**, 220, 1908, it was shown that the evidence then available indicated the existence of a strong magnetic field in sun-spots. A summary of the results hitherto obtained in this investigation is given below:—

(1) In the spectra of sun-spots most of the Fraunhofer lines are widened, some are changed to doublets (incompletely resolved quadruplets), and some to triplets. Others probably have a still more complex structure.

(2) The component lines of spot doublets are circularly polarized in opposite directions (longitudinal effect in a magnetic field).

(3) Many lines not resolved in the spot spectrum are displaced when the Nicol (used with a Fresnel rhomb before the spectrograph slit) is rotated.

(4) When the Nicol, used with rhomb, is set at a certain angle, it transmits the red components of doublets in the spectrum of a right-handed vortex, and the violet components in a left-handed vortex.

(5) Although the larger spots in the northern and southern hemispheres of the Sun are usually found to be of opposite polarity, it frequently happens that spots of opposite polarity occur in the same hemisphere, sometimes in the same spot group.

(6) Triplets have been found in all our best photographs of spot spectra, including those taken when the spot was near the center of the Sun.

(7) The central component of such triplets is plane polarized, while the outer components are elliptically polarized.

(8) Many lines which are widened but not resolved in spot spectra can be shown to be triplets by cutting out the central component with a Nicol placed at a suitable angle.

(9) Under certain conditions, when a Nicol is used, the central line of a spot triplet is present on one side of the spot

and absent on the other. Rotation of the Nicol through 90° reverses the appearance, causing the line to appear on the side where it was previously absent and to disappear on the opposite side. This effect is provisionally attributed to the rotation of the plane of polarization of the plane polarized light emitted by the central line, when passing outward through the spot vapors.

(10) The width of the components of a spot triplet sometimes varies with the position of the Nicol. This may be the result of the combined effect of the rotation of the plane of polarization and the rapid decrease upward in the strength of the field above the spot.

(11) The intensity of the central line of spot triplets varies with the position of the spot on the Sun's surface, and is greatest near the limb.

(12) The intensity of the central line in a spot near the center of the Sun is such as to indicate that the lines of force of the magnetic field usually make a considerable angle with the solar radius passing through the spot.

(13) Lines which appear as doublets in the spot spectrum are found in the laboratory to be doublets when observed along the lines of force, and quadruplets when observed across the lines of force. With the dispersion available, such lines cannot be resolved into quadruplets in the spot spectrum.

(14) Spot triplets are found in the laboratory to be triplets when observed across the lines of force.

(15) Certain triplets and quadruplets of iron show nearly the same relative separation of their components in spot and laboratory.

(16) From the measurement of such lines, the maximum strength of the field is found to range from 2900 to 4500 C. G. S. units in different spots.

(17) The strength of the field is generally greatest near the center of the umbra and decreases gradually in intensity across the penumbra.

(18) An appreciable field is shown by certain lines to extend beyond the boundaries of the penumbra.

(19) Magnetic fields have also been found on the solar disk entirely outside of sun-spots.

(20) The doublets and triplets of iron give the strongest fields hitherto measured in sun-spots. The *D* lines of sodium and the *b* lines of magnesium, which are produced at a higher level in the solar atmosphere, indicate a much weaker field. The hydrogen lines over sun-spots, representing a still higher level, give no indication of a magnetic field. It therefore follows that the strength of the field in sun-spots rapidly decreases in passing upward from the surface of the photosphere.

(21) Preston's law, $\frac{\Delta\lambda}{\lambda^2} =$ const., is closely followed by iron doublets observed in the laboratory (using mean values of $\Delta\lambda$) and approximately so by spot doublets.

(22) The degree of widening of unresolved lines in the spot spectrum decreases rapidly from the red to the violet, and is roughly proportional to the separation of their components in the laboratory.

(23) A direct relationship appears to exist between the strengthening and the widening of lines in spot spectra.

(24) As the strength of the field is greatest at low levels, it appears probable that the electric vortex which produces the field lies within the photosphere.

(25) The strength of the field in sun-spots is not sufficient to account for magnetic storms on the earth.

Charts of the magnetic fields in sun-spots, showing their strength and polarity in all parts of a spot group and the surrounding regions, are made photographically as follows:—

Above the spectrograph slit a Fresnel rhomb (or a quarter-wave plate) and a Nicol prism are mounted, the position of the Nicol being such as to cut off one of the side components of a triplet. A series of exposures is then made, with the slit set across different parts of a spot group. The spot lines thus photographed are distorted, the red components appearing in spots of one polarity, the violet components in those of the opposite polarity. The displacement of the components from the normal position of the line is proportional to the strength of the field. It frequently happens that closely adjoining spots in the same group are of opposite polarity. In a recent case (September 25, 1909) a large spot was accompanied by four small spots, all lying within the same penumbra. The polarity of the magnetic field in the penumbra (on the side away from

the small spots) was the same as that of the large spot. All of the small spots, however, were of opposite polarity. Between the large and small spots the magnetic fields of opposite polarity counteracted one another, reducing the strength of the resultant field to zero. This is shown on the photographs by the form of the lines: the red components bend sharply back from the position of maximum displacement over the large spot to the normal position of the line, where they cross to the violet side, returning again to normal in the region beyond the small spots.

By means of a series of parallel slits, the spectra of from six to ten sections of a spot group can be photographed simultaneously, in parallel strips on a single negative. A simple apparatus then permits images of any desired line in this negative to be photographed side by side, in the same relative positions as the parallel slits of the spectrograph. A photograph of the hydrogen flocculi, made with the $H\alpha$ line, is then copied on the same plate.[1] The composite image shows the strength and polarity[2] of the magnetic fields along the lines occupied by the slits, and permits the relationship between the magnetic fields and the curvature of the streamers in the $H\alpha$ vortices to be investigated. Results already obtained with provisional apparatus show this relationship to be an intimate one.

GEORGE E. HALE.

SPECTROGRAPHIC AND PHOTOGRAPHIC OBSERVATIONS OF COMET *c* 1908 (MOREHOUSE).[3]

So exceedingly faint was the nucleus of this comet that great difficulty was experienced in securing a slit spectrogram. An exposure was finally made with the one-prism spectrograph of the D. O. Mills Expedition extending over seven hours and twenty-nine minutes on the nights of February 24, 25, and 26, 1909. The width of the slit was 0.5^{mm} and precautions were taken to keep the temperature of the

[1] Perfect registration is readily secured by the aid of a photograph of the spot group, reflected from the polished slit jaws into a camera, showing the exact positions of the slits with reference to the spots.

[2] With high dispersion the direction of the field can also be determined by the intensity of the central line of a triplet.

[3] Abstract of *Lick Observatory Bulletin*, No. 163.

prism at the same point during all three exposure epochs and for several hours before commencing work. Only the strongest of the pairs, that at λ 4255-76, can be made out on this plate, and the resulting wave-lengths are λ 4254.2 and λ 4275.4.

Between February 24th and March 23d seventeen objective-prism spectrograms of the comet were secured, nearly all of them very faint. The resulting wave-lengths are:—

λ 3914.1	9 plates	
4002.1 4021.3	15 plates	
4254.0 (4276.0)	17 plates	
4526±	3 plates	Very difficult
4545.9 4570.2	16 plates	
4690.7 4716.3	4 plates	Difficult

In determining the wave-lengths given above, the line at λ 4276.0 was assumed as known.

Collecting the differences for the three strongest pairs of lines, λ 4002-21, λ 4254-76, λ 4546-70, together with the corresponding angles at the comet between the radius vector and the line connecting the comet with the Earth, we have:—

Observer.	Date.	$\Delta\lambda_1$	$\Delta\lambda_2$	$\Delta\lambda_3$	Angle.
DESLANDRES and BERNARD......	1908 Oct. 14	20	23	20 ±	39°.9
DESLANDRES and BOSLER........	Nov. 1	19.7	21.6	22.0	46 .3
CAMPBELL and ALBRECHT.......	Nov. 28	19.6	20.7	20.8	37 .2
CURTIS	1909 Feb. 25	18.5	22.0	24.5	39 .7
CURTIS	Mar. 21	19.4	22.5	23.8	35 .6

The objections to the explanation of the doubling of these lines as a Doppler-Fizeau effect have already been well put by CAMPBELL and ALBRECHT.[1] Assuming the actual velocities along the tail or transverse to the tail to have been the same on November 1, 1908, and March 21, 1909, the mean of the intervals for the three principal pairs of lines should have been about four tenth-meters greater, or less, respectively, on March 21st than on November 1st; whereas the observed

[1] cf. *Lick Observatory Bulletins*, 5, 64, 1909.

intervals are not quite one tenth-meter greater on the latter date.

The stronger objective-prism plates show the tail, though very faintly, to a distance of two to two and a half degrees from the head, and in all cases the tail is apparently a replica of the direct photographs taken at the same time, as far as can be made out on the small scale of the plates. In this respect a plate taken on March 20th is of especial interest; on this night the direct photograph shows a marked curve in the tail about half a degree from the head, a curve which is duplicated in each of the spectral images.

Twenty-eight direct photographs were also secured, the majority of these being taken with a portrait lens of 6⅛ inches aperture; many of these direct photographs show interesting evidences of the extraordinary activity which seems to have characterized this comet, both before and after perihelion.

HEBER D. CURTIS.

THIRTEEN STARS HAVING VARIABLE RADIAL VELOCITIES.[1]

In the progress of the work of the D. O. Mills Expedition to the southern hemisphere it has been found that the following stars have variable radial velocities:—

Star.	α	δ	Mag.	Type.	Range, km	Discoverer.
A.G.C. 8017	$6^h\ 28^m.9$	$-31°\ 57'$	5.7	B3A	$+\ 5$ to $+41$	CURTIS
A.G.C. 9276	7 13 .3	-36 25	5.0	B3A	-19 to $+41$	PADDOCK
ϵ Volantis	8 7 .6	-68 19	4.5	B5A	-29 to $+45$	CURTIS
H Velorum	8 53 .3	-52 21	4.8	B5A	$-\ 4$ to $+68$	PADDOCK
β Crateris	11 6 .7	-22 17	4.5	A2F	$-\ 7$ to $+12$	PADDOCK
A.G.C. 15975	11 36 .2	-61 32	4.9	G	$-\ 4$ to $+23$	PADDOCK
θ^2 Crucis	11 59 .2	-62 36	5.0	B3A	-19 to $+47$	PADDOCK
A.G.C 19597	14 23 .7	-49 4	5.5	A2F	Both spectra	CURTIS
e Lupi	15 6 .1	-44 8	4.9	B3A	$-\ 8$ to $+29$	CURTIS
ζ Trianguli Australis	16 17 .6	-69 52	4.9	G	$-\ 2$ to $+17$	CURTIS
δ^1 Telescopii	18 24 .4	-45 59	5.0	B8A	-72 to $+27$	CURTIS
δ^2 Telescopii	18 24 .7	-45 49	5.3	B5A	$-\ 9$ to -29	CURTIS
ι Pisc. Australis	21 39 .0	-33 29	4.4	A	Both spectra	CURTIS

With the exception of two plates on A.G.C. 15975, all the plates were taken with the two-prism spectrograph.

HEBER D. CURTIS.

[1] Abstract of *Lick Observatory Bulletin*, No. 164.

Observations of Halley's Comet.

Search for Halley's Comet was begun early in September with the Crossley Reflector, although at this time the fogging effect of the moon rendered success more than doubtful. Owing to very high wind and poor observing conditions the nights of September 10th and 11th were not usable. The plate of September 12th shows the comet as a small, slightly elongated nebulous mass about five seconds of arc in diameter. The following positions have been derived from the photographs made with the Crossley Reflector:—

1909	P. S. T.	App. α	App. δ	Parallax factors. α	Parallax factors. δ
Sept. 12,	$14^h\ 30^m\ 19^s$	$6^h\ 18^m\ 28^s.89$	$+17^\circ\ 10'\ 53''.9$	9.655n	0.632
13,	15 42 20	18 37 .50	10 28 .2	9.563n	0.568
14,	15 29 41	18 45 .03	10 7 .4	9.578n	0.576
22,	15 8 45	19 4 .57	6 56 .5	9.555n	0.565
22,	16 8 52	19 4 .42	6 55 .6	9.416n	0.523

The position of September 14th rests upon five comparison stars, the others upon four each. On September 14th the magnitude was about 15.5.

Heber D. Curtis.

Note on the Pan-American Congress.

Dr. H. D. Curtis acted as the delegate of the University of Michigan to the first Pan-American Scientific Congress, held in Santiago from December 25, 1908, to January 5, 1909, presenting the following papers before the section of pure and applied mathematics:—

(1) Problemas astronómicos del hemisferio sur (Astronomical Problems of the Southern Hemisphere).

(2) Las velocidades radiales de estrellas australes con grandes movimientos propios (Radial Velocities of Southern Stars with Large Proper Motions).

(3) Estrellas dobles australes descubiertas con el espectroscopio por el Observatorio de la D. O. Mills Expedición (Spectroscopic Binaries Discovered at the Observatory of the D. O. Mills Expedition).

W. W. Campbell.

TELEGRAM.

LICK OBSERVATORY, September 14, 1909.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass.

CAMPBELL and ALBRECHT compared spectra *Mars* and the Moon on Mount Whitney, September 1 and 2. Little *a* water-vapor bands estimated equal intensities and very faint. Zenith distance 42°, barometer 450 millimeters, air temperature —1° Centigrade, wet thermometer —8°.

W. W. CAMPBELL.

Unfortunately "little" and "*a*" were transposed at some point in the transmission of the telegram to other observatories.

W. W. C.

REPORTS OF OBSERVATORIES.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

This report covers the period January 1, 1908, to July 1, 1909. It is intended that only the more important items of the activity of the observatory shall be considered, and these quite untechnically.

The total solar eclipse of January 3, 1908, was observed by means of an expedition dispatched from the observatory through the generosity of Honorable WILLIAM H. CROCKER, regent of the University of California. A popular account of the expedition and its work has already appeared in these *Publications,*[1] and its general features need not be repeated here. In spite of clouds which interfered with carrying out the program during the first third of the total phase, subsequent studies of the photographs showed that the expedition met with an unusual measure of success.

Dr. PERRINE completed his detailed examination of the sixteen photographs, obtained with eight cameras, covering the region 9° by 28° extending in the direction of the Sun's equator. These photographs had for their purpose the detection of any existing intermercurial planet or planets. In the sudden downpour of rain immediately preceding totality it was not possible to protect everything, and a little water got into these cameras. Some of the photographs are marked by narrow bands where the rain water ran across them. Until after our return to Mount Hamilton it was thought the photographs were damaged to such an extent that the value of the intermercurial search was seriously impaired, and our public announcement embodied this view. It is gratifying to state that these fears were groundless. There are images of more than five hundred stars on the photographs, down to about the ninth magnitude; and, surprising to relate, the rain-streaked areas contain the images of all the known stars we expected to find thereon. All the images have been identified as those of well-known stars. In our opinion, the work of the three Crocker Expeditions, to observe the eclipses of 1901, 1905, and 1908, brings the observational side of the intermercurial planet prob-

[1] **20**, 63, April, 1908.

lem—famous for half a century—definitely to a close. It is not contended that no planets will be found in the intermercurial region: it would not be especially surprising nor in contradiction to beliefs here expressed if small planets should be discovered at some future time; but it is confidently believed that their mass would be inadequate to account for the observed disturbances in the motion of *Mercury*.

The photographs of the solar corona obtained with cameras of 6′ and 40′ focal lengths are of great excellence. Opportunity has not been found to study these photographs as completely as we should like, and attention will be called to only one feature. A great number of coronal streamers appear to radiate from a common point near the eastern limb of the Sun (position angle 75°), as if thrown out by an explosion at the point, though it is not contended or even suggested that an explosion had actually occurred. The point of intersection of the streamers, obtained by prolonging them behind the Moon's disc, was estimated to be in position angle 75° and the distance from the Sun's center 13.′7 of arc. On comparing this position with the photographs of the hemisphere of the Sun turned toward us, as obtained by the Mount Wilson Solar Observatory on January 3d, 4th, and 5th, it was apparent that the vertex of the so-called disturbance was situated within the borders of a great group of sun-spots. It may be recalled that a similar cone of disturbance, as recorded on the Sumatra corona plates of 1901, appeared to have its vertex exactly over the large and only spot recorded on the photographs of the sun obtained on several days preceding and following the date of the eclipse; and that another radiating group of coronal streamers on the Spanish photographs had their estimated apex near, but apparently not in coincidence with, a prominent sun-spot. In view of these pieces of evidence, it is difficult to avoid the conclusion that the sun-spots and the coronal streamers referred to were closely related in origin.

Spectrograms of the corona obtained by Dr. Lewis and Director Campbell, using different instruments, recorded a large number of coronal bright lines, of which four observed by Dr. Lewis and two by Mr. Campbell are certainly new. The interpretation of the continuous spectrum of the corona is a difficult matter. The records are rendered very complex

by the diffusion of light of the solar prominences and of the brilliant inner corona over the whole area of the spectrum. The dark-line spectrum believed to be due to photospheric light scattered by minute particles in the corona is visible very faintly, and only in the region of the corona well out from the Sun's surface. By far the greater part of the light gives a strictly continuous spectrum, and seems to be due to radiation from the coronal particles perhaps rendered incandescent by the overpowering heat of the Sun. The position of maximum intensity of continuous spectrum is displaced slightly toward the red from that of the normal solar spectrum, signifying the lower temperature of the corona.

The changing spectrum of the Sun's edge, as the edge was gradually uncovered by the Moon, was recorded successfully on a continuously moving sensitive plate. More than a thousand bright lines, changing into the dark lines of the ordinary solar spectrum, were impressed on the plate in lengths and at times such that they indicate the thicknesses and locations of the gaseous and vapor strata giving rise to them in the Sun's atmosphere. Four such photographs, obtained at the eclipses of 1899, 1900, 1905, and 1908, respectively, may be said to constitute a unique basis for the study of chemical stratification of the solar atmosphere. The moving plate has a great advantage over the fixed plate in recording the spectrum of the Sun's edge, in that the former gives a continuous record of all changes occurring, whereas the latter gives an integrated record for the brief period of exposure only.

From photometric observations of the Flint Island corona, Dr. PERRINE has deduced the following results, the unit of brightness being the light from one square minute of arc of flame of a Hefner standard lamp:—

Total actinic light of portion of corona observed	222 units
Intrinsic actinic brilliancy of corona	2.02
Intrinsic actinic brilliancy of sky near corona..	.0027
Ratio of intrinsic actinic brilliancy of the brightest parts of sky	744 to 1
Total actinic light of full Moon	2002 units
Intrinsic actinic brilliancy of full Moon	2.58
Ratio of total coronal to full Moon light......	0.111

A series of photographs for the study of polarization effects in the corona was obtained. The Rumford Committee of the

American Academy of Arts and Sciences has made a grant for the purchase of a photometer suitable for the measurement of these and other similar plates, and it is hoped that they may be subjected to quantitative analysis in the near future.

Dr. AITKEN has continued the double-star survey of the northern sky, according to the systematic plans described in my last report. It is expected that this survey, as carried on at Mount Hamilton, will extend to —22° declination. About 90% of the survey has been completed; and given ordinary observing conditions in the following two winters and springs, the program should be completed. More than 3,300 close pairs of stars have been discovered as one result of this survey: 1,300 + by Professor HUSSEY and 2,000 + by Dr. AITKEN. The two components of each double are in fully 99% of the cases less than 5″ of arc apart.

It is scarcely necessary to say that the great value of this survey lies not in these discoveries themselves, but in the enormously increased opportunity which the discoveries will afford in the future study of double stars, in particular, and of the structure of the sidereal universe, in general. Holding the requirements of these studies in mind, the systematic qualities of the search are rigidly maintained; and at least two satisfactory micrometer measures of each pair are secured as promptly as practicable, before announcing the discovery. It is hoped, for example, that future computers of their orbits will have the great advantage of an accurate discovery position in each case.

About one hundred of the more important and more difficult of our well-known double stars are kept under observation by Dr. AITKEN, measures being made as often as they are needed. It has been found that the revolution period of 13 *Ceti* is only 7.4 years; next to that of *Delta Equulei* the shortest period known.

Astronomer TUCKER having been offered the superintendency of the Meridian Circle Station of the Carnegie Institution, in the Argentine Republic, the regents of the University were pleased to grant him leave of absence for the three academic years 1908-1911, in order that he might accept this highly honorable appointment. The remarkably large quantity of very accurate results secured by Mr. TUCKER during his fifteen

years' residence on Mount Hamilton had given rise to a widespread feeling among the specialists in his subject that he was the man for the place. It was largely in response to this opinion that the director recommended the loan of Mr. TUCKER's services, involving as it did a serious interruption to our own program of observations. He left Mount Hamilton on May 1, 1908. His observations during the preceding four months, continuing his work of the preceding two years, related to the program for determining the extremely accurate positions of stars, based on fundamental methods as opposed to basing results upon a system of star positions already established with other instruments. The stars in his program are distributed nearly uniformly between 37° north and 37° south declination. Special stars are included for the purpose of determining the observer's personal errors as affected by his facing north or south while making the observations and by the direction of the apparent motion of the star through the field of view. Suitable stars for the investigation of atmospheric refraction were included, and likewise a list of stars to determine the effect of star magnitudes upon the personal equation. The reductions of the observations for the period of more than two years are well advanced, thanks to assistance afforded by the Carnegie Institution.

Much of Astronomer PERRINE's time has been devoted for several years to devising methods of measuring and reducing the long series of *Eros* photographs taken in 1900 with the Crossley reflector, for the determination of the solar parallax; and to superintending this work. The measurements and computations, based upon 525 photographs, were made by Mrs. MOORE and Miss HOBE, Carnegie Assistants, beginning with December 1, 1905. The results of the measurement were brought together by Dr. PERRINE last winter, and a critical discussion led to the most probable value of the solar parallax, $8''.8067 \pm 0''.0025$. This result is in remarkably good agreement with the longer series of observations secured at other stations. The details of the measurements and discussions will be brought out in a volume to be published soon by the Carnegie Institution.

During the period covered by this report about one hundred and fifty photographs were made with the Crossley reflector,

chiefly by Dr. PERRINE and in part by Dr. ALBRECHT and others. The subjects included the faint satellites of *Jupiter,* nebulæ, star clusters, parallax objects, etc.

During the summers of 1907 and 1908 Mr. FATH made an extensive study of the zodiacal light with reference to polarization effects, the character of its spectrum, and its maximum extension northward from the ecliptic or Sun's equator. The spectrum observations are not yet ready for publication. The northern extension of the zodiacal light was observed satisfactorily, and there is left no doubt that it can be seen approximately 45° northward from the Sun, as viewed by a terrestrial observer.

Mr. FATH photographed the spectra of several spiral nebulæ and globular star clusters with a low dispersion instrument attached to the Crossley reflector. The text-books on astronomy ascribe in most cases a continuous spectrum to spiral nebulæ. Mr. FATH found that their spectra vary from those having principally bright lines, such as are found in the so-called gaseous nebulæ, to those containing only absorption lines of the solar type. No strictly continuous spectrum was observed. He confirmed in the strongest possible manner the earlier observations by SCHEINER and HUGGINS on the *Andromeda* nebula, removing any elements of doubt which may have attached to their results, to the effect that the spectrum of this object is of the solar type. The spectra of globular star clusters, including the great cluster in *Hercules,* are continuous, with a certain number of well-defined absorption lines. In general, stars of the so-called "F" type appear to predominate in the clusters. This type occupies a position about midway between the hydrogen stars and solar-type stars.

Micrometer observations of comets visible during the period have been obtained chiefly for the use of the Berkeley Astronomical Department in determining orbits. The spectrum of Comet Morehouse was studied by Messrs. CAMPBELL and ALBRECHT at Mount Hamilton, in the fall months of 1908, and by Astronomer CURTIS at the D. O. Mills Observatory in Chile, in the spring of 1909. The spectrum was essentially of a new type. The carbon and cyanogen bands usually visible in cometary spectra were relatively faint, and other sets of lines appearing in pairs were for the most part new and of remark-

able strength. Readers are referred to *Lick Observatory Bulletins* 145 and 147 for detailed particulars. It was suggested by one noted astronomer that the doubling of the lines was a Doppler effect, due to relative motions in the observer's line of sight. Not only did this hypothesis seem extremely improbable, but our observations in the two hemispheres showed that it could not be true, for the varying angles under which the comet was observed should have been accompanied by corresponding variations in the intervals between the lines of the pairs. These intervals remained, on the contrary, essentially constant.

Miss GLANCY, fellow in the Lick Observatory, secured a splendid series of photographs of Comet Morehouse. Her measurements and discussion of the plates and the reproductions of a large number of the photographs are in process of publication. Dr. CURTIS's photographs of the comet and its spectrum will be published in the course of a few months.

Mr. DUNCAN, fellow in the Lick Observatory, made a systematic investigation of the two variable stars, Y *Sagittarii* and RT *Aurigæ*, and discussed the possible causes of the type of stellar variation represented by these stars. The basis of his studies consisted of spectrograms obtained with the one-prism and three-prism Mills spectrographs attached to the 36-inch refractor. The causes of the variation appear to be exceedingly complex, and several in number. Tidal disturbance, motion in a resisting medium, and an atmosphere of variable absorptive powers were considered. No one of these is in itself sufficient to explain the variations of brightness observed, and it is not improbable that two or more of them, along with other causes, are acting. The studies of a dozen stars belonging to this type of variation, made chiefly by fellows of the Lick Observatory, have furnished a very considerable amount of valuable evidence bearing on the problem. The most significant fact established, by Dr. ALBRECHT, is that the maximum brilliancy in each case studied occurs when the star has its greatest velocity of approach toward the observer. There is little reason to doubt that an observer viewing the star from any point in our universe would in every case have maximum brilliancy when the star was approaching him. Studies of other stars of the same type are

extremely desirable, in order to make investigations of this type as a whole more effective.

The most extensive investigation under way is that of determining the radial velocities of the brighter stars by means of the Mills spectrograph attached to the 36-inch refractor, in the northern hemisphere, and by the D. O. Mills Expedition observing at Santiago, Chile, in accordance with a program determined upon by Mr. CAMPBELL in 1896. This program hopes to include all the stars whose visual magnitudes do not fall below 5.0 in the two hemispheres, using three-prism dispersion; with the addition of a considerable number of fainter stars in the southern hemisphere, using two-prism dispersion. The number of stars observed prior to June 1, 1909, at Mount Hamilton, is nearly 900, but approximately 200 of these have been temporarily rejected for observation with lower dispersion, because the lines in their spectra are too broad and ill-defined for accurate measurement. All the spectrograms secured prior to May, 1903, have been measured and reduced definitely; and about three fourths of those obtained between 1903 and 1909 have been similarly studied. In the southern hemisphere observations have been secured of 530 stars brighter than 5.0 and of about 150 stars fainter than 5.0 visual magnitude. The spectrograms of 148 stars observed by the D. O. Mills Expedition during its first period of work, in charge of Astronomer WRIGHT, have been completely measured and discussed, and both numerical results and accompanying text are entirely ready for the printer. Twenty-nine of the 148, or more than one in five, have been announced as spectroscopic binary stars. Of the spectrograms obtained during the second period of the expedition, in charge of Astronomer CURTIS, those made with three-prism dispersion have nearly all been measured and reduced; and those secured with two-prism dispersion have been submitted to approximate measurement and reduction.

Deducting stars observed in both hemispheres, the total number observed is 1,368.

The measurement and reduction of Mount Hamilton spectrograms have been invaluably assisted by grants from the Carnegie Institution.

In June, 1909, Dr. MOORE succeeded Dr. CURTIS as astronomer in charge of the D. O. Mills Expedition, the latter return-

ing to Mount Hamilton to take up the work of Astronomer PERRINE, resigned.

The orbits of a considerable number of spectroscopic binary stars have been determined by Messrs. CURTIS, MOORE, and PLUMMER.

The record of spectroscopic binary stars discovered, observed, and investigated is complete to date, and it is our purpose to publish a second catalogue of spectroscopic binary stars next winter.

Volume VIII of the *Publications of the Lick Observatory,* containing heliogravure, hand-press reproductions of seventy of Professor KEELER'S photographs of nebulæ, taken with the Crossley reflector, was issued in December, 1908. The arduous task of preparing the glass positives of just the right density to meet the engravers' requirements and of reading the proofs was borne by Dr. PERRINE. The preparation of the copper plates, coupled with much experimental work, extended through nearly four years. We struggled to reproduce the delicate details of the structure in both the bright and faint regions of the nebular subject and to preserve the natural dark sky backgrounds. As the engravers acquired experience and skill in dealing with our photographs, better and better results were secured; but we were forced to recognize that only the original negatives or copies on glass will suffice for the most exacting scientific requirements. We are hoping to place a set of positive copies on glass in each of half a dozen scientific centers of population, where they will be accessible to all qualified students of the subject. The expenses of the KEELER Memorial Volume were so heavy that the work could not have been carried through but for the generous help of many friends of the observatory.

It has been held in mind for several years that our most pressing duty relates to the publication of extensive results of observations as yet unpublished; and an ambitious program of publication was formulated for the biennial period just begun. With the approval and support of the regents of the university, the legislature which recently adjourned was asked to appropriate funds to carry out my program of publication. For reasons not connected with the observatory and therefore quite beyond my control, the increased appropriations were

not made. In fact, the actual appropriations for the biennial period are smaller than usual. Those available in the academic *year 1909-10 were consumed as soon as available* to meet deficits arising from printing for this and other departments of the university; and funds available for the year 1910-11 have been applied in good part to the same end. Efforts must be made to secure publication funds elsewhere. With the best of legislative intentions toward this observatory, we sometimes find it difficult to meet the expectations of other and distant astronomers in maintaining an international reputation on the basis of appropriations coming in meagerness from only one State of our own Nation—a generous State, whose finances were sorely tried by the catastrophe of April, 1906. The regents of the University of California, receiving their chief support from State funds, would gladly grant increased support to this department, I believe, if funds were available. The funds received from the university for the salaries of astronomers and astronomical assistants have been practically constant, since the beginning, in 1888, at $14,000 per annum. In the meantime the purchasing power of money has decreased fully one third.

Immediately following the completion of the KEELER Memorial Volume, we planned to begin with the reproduction of our long series of solar coronas, coronal spectra, etc., as illustrations for the proposed volume to contain the results of the Crocker Eclipse Expeditions to India, Georgia, Sumatra, Egypt, Spain, and Flint Island. It is hoped that efforts to secure funds for carrying on this work may soon be successful.

The number of *Lick Observatory Bulletins* issued to date is 160. This form of publication has been curtailed in the past three years to conform to *reduced* appropriations and greatly *increased* prices of printing. The special appropriation for the purpose has also borne the expense of printing and mailing brief *Bulletins* for the Berkeley Astronomical Department.

The half of a fire and earthquake-proof building, with several storage vaults to contain our invaluable collection of celestial photographs and rooms suitable for the development, enlargement, measurement, and study of the photographs, was erected late in the year 1907. The regents of the university recently appropriated funds to complete the building. The

construction is at present under way and the building should be complete in October, 1909.

During years of normal rainfall the water supply, depending in the dry summer and fall months upon the storage capacity available, has been sufficient to meet the needs of households, photography, etc.; but in years of short rainfall it has been necessary to curtail the consumption. A serious shortage occurred in the fall and winter of 1908. The regents of the university recently authorized the construction of a steel storage tank with capacity of 160,000 gallons. This tank is under construction and should be available for the storing of water during the rainy months of the winter, for consumption in the latter half of 1910.

A beginning has been made in the planting of trees immediately around the summit occupied by the main buildings. Assistance has been received from the U. S. Forestry Bureau. It is hoped that the afforestation near the summit of the mountain may proceed on a liberal basis from year to year.

At the request of the Navy Department of the United States Government, we determined the longitude of the Naval Observatory at Mare Island, California, with reference to the assumed longitude of the Lick Observatory.

The Lick Observatory has suffered great loss in the departure of Astronomer CHARLES D. PERRINE to assume the directorship of the National Observatory of the Argentine Republic. Coming to Mount Hamilton in the capacity of secretary in March, 1893, Mr. PERRINE's ability, energy, and interest carried him rapidly forward in an astronomical career. He was appointed astronomer in the Lick Observatory in 1905. The results of his work are well known to the readers of these *Publications*. Suffice it to say that his services were of unusually great efficiency, and the many honors which have come to him were fully earned. He left Mount Hamilton with the personal goodwill of all his associates. The chief attraction of his new post of duty lies in the opportunity which the largely undeveloped state of astronomy in the southern hemisphere presents. It is confidently expected that he will give a good account of his stewardship.

W. W. CAMPBELL,
Director.

June 30, 1909.

GENERAL NOTES.

The Meeting of the Astronomical and Astrophysical Society of America.—The tenth annual meeting of the Astronomical and Astrophysical Society of America was held at the Yerkes Observatory, Williams Bay, Wisconsin, August 18-21, 1909. The regular sessions for the presentation and discussion of papers and for the transaction of business by the society did not begin until Thursday morning, August 19th, but the Council of the society met at the observatory on Wednesday evening, and by the courtesy of Director Frost and Professor Burnham all members of the society who were present were given an opportunity to look through the 40-inch telescope, under Professor Burnham's direction. Fortunately the sky was clear and the seeing fair, and, indeed, the society was favored with almost ideal weather throughout its sessions. The preceding week had been one of sultry and oppressive heat, but a heavy electrical storm on Monday night cleared the atmosphere, so that the following days of the week were only pleasantly warm and the nights for the most part clear.

This initial courtesy on the part of the staff of the Yerkes Observatory was only an indication of the cordial hospitality shown by them to the society throughout the following days. In the secretary's announcements of the meeting it was stated that members attending would be able to secure convenient quarters at Point Comfort on Lake Geneva, not far from the observatory buildings; but on our arrival we found the members of the staff insisting upon entertaining as many of us as their house-room would permit. The present writer had the very great pleasure of spending the three days as the guest of Professor and Mrs. Barnard. Not content with this, we were all entertained at lunch each day by Mrs. Frost and the other ladies; Mrs. Frost's house was open for a reception and tea at the close of the Thursday afternoon session; the observatory was thrown open for general inspection, under guidance of the staff, on Friday before the afternoon session, and at the close of that session, by courtesy of Mr. Ryerson and other residents on the lake shore, we were treated to a launch ride about Lake Geneva.

I have purposely mentioned the social features of the week before giving any account of the sessions themselves, for, after all, the most profitable part of such a meeting is the opportunity it offers for the better mutual acquaintance of workers in related lines of research and for the free interchange of views, and the social gatherings served these ends perhaps even better than the formal discussions of the papers. The fact that there was a very large attendance of members from all parts of the country—over fifty being registered—made this meeting an unusually favorable one for the promotion of acquaintanceship.

The papers themselves were of the greatest interest, and there were forty-two of them. Many of them, as, for example, PARKHURST's "Precautions Necessary in Photographic Photometry," MOULTON's "Some Considerations of Globular Star Clusters," and BARNARD's "On the Photographs of Comet *c* 1908 (MOREHOUSE)," led to considerable discussion. The last-named paper, like many others, was fully illustrated by lantern slides, and opportunity was also given for examining the beautiful stereoscopic views that Professor BARNARD has prepared from his negatives of this comet.

It is impossible to give here even by title all the papers presented for our consideration. They treated, among other topics, of new designs of instruments, cameras, spectrographs, etc., new plans for tabulating the Moon's longitude, the problem of three bodies from the standpoint of spectroscopy, a proposed method of studying solar radiation at great altitudes, reports of progress in various researches, the spectrum of meteors, and the present needs of astronomy.

Aside from the formal papers, several other reports and resolutions were presented that aroused interesting discussions. Among these was a resolution relating to the current newspaper articles on signaling to *Mars*. It was finally decided that a statement should be prepared by a committee, the wording to be at their discretion, to the effect that in the present state of our knowledge it did not seem necessary or desirable for the society seriously to consider this matter.

The proposed change of name of the society to "The American Astronomical Society" was also discussed at some length, but the present name was retained by a decisive vote.

Professor COMSTOCK gave the report for the Committee on Comets. In brief, he stated that arrangements had been made that would make it possible to photograph Comet Halley from practically all longitudes on the Earth; for means will be forthcoming to bridge the great gap between the Lick and Solar observatories in California and observatories in Eastern Asia, by providing a temporary station at a suitable point in the Pacific Ocean. The committee had also secured promises that Professor BARNARD would outline a program of photographic observations, Professor FROST one of spectrographic observations, and Professor E. C. PICKERING one of photometric observations on this comet. These programs will be presented to astronomers in ample time to permit general co-operation in their execution.

Abstracts of all the papers presented will be printed in *Science* in the near future. It was also decided to issue a pamphlet giving a *résumé* of the history of the society and of the ten meetings so far held, the pamphlet to include also the constitution and by-laws of the society and a list of members.

R. G. AITKEN.

Two New Calculating Tables.—Dr. J. PETERS: Neue Rechentafeln für Multiplication und Division mit allen ein—bis vierstelligen Zahlen. G. REIMER, Berlin, 1909.

Dr. O. LOHSE: Tafeln für numerisches Rechnen mit Maschinen. W. ENGLEMANN, Leipzig, 1909.

It is the experience of all who find it necessary to carry through extended computations that it is scarcely possible to have at hand too many tables and other helps for the rapid performance of the different processes involved; it will be found that these two excellent tables will at once fill a distinct gap which has hitherto existed in the working library of every computer. Dr. PETER'S Rechentafeln contain the products of all one- and two-figure numbers by all numbers up to 9,999, making it possible to take out the product of two four-figure numbers from the same half-page, with only about one half the labor involved in performing the same process with CRELLE'S Tables. For all work, least squares, etc., necessitating the use of four figures, it will be found a great time-saver. Moreover,

the numbers ending in a cipher are not omitted, as in the older edition of CRELLE, a convenience which will be appreciated by the practised computer, and a liberal use has been made of rulings and spacings so as to save the eye as far as possible from the strain incident to selecting figures from a solid, unbroken page.

LOHSE's Tafeln have been published to facilitate the greatly increasing use of the calculating machine. The first table gives the reciprocals of numbers to five places, thus making it possible to eliminate division, always more troublesome than multiplication with the calculating machine. Following this is a five-place table of the natural trigonometric functions to each hundredth of a degree; in this table all six functions are given—sine, cosecant, tangent, cotangent, secant, and cosine. Tables of square roots, and a convenient collection of trigonometrical and differential formulæ close the book. The arrangement and typography are excellent.

H. D. C.

Notes from "Science."—A bronze memorial tablet in honor of the late Dr. GEORGE W. HOUGH has been unveiled with appropriate exercises in the Dearborn Observatory of Northwestern University.

The University of Rochester, Rochester, New York, has received under the provisions of the will of the late Rear-Admiral WILLIAM HARKNESS, professor of mathematics, U. S. N., almost his entire large and valuable collection of astronomical and scientific instruments and a considerable part of his library. The instruments, including an Alvan Clark telescope, comprised the equipment for a private observatory he intended to erect. The devise of books included over sixteen hundred volumes and about seven thousand unbound periodicals and pamphlets. The university has placed the works on astronomy and physics in a separate section of its library, as the basis of a scientific department, to be known as the Harkness Scientific Library.

Mr. PHILIP FOX, hitherto instructor in astrophysics at the Yerkes Observatory, University of Chicago, assumed the duties of professor of astronomy in the Northwestern University and director of the Dearborn Observatory, Evanston, Illinois, on

September 1st. He is succeeded at the Yerkes Observatory by Dr. FREDERICK SLOCUM, for several years assistant professor of astronomy at Brown University, who has just returned from a year in Europe, principally spent at the Royal Astrophysical Observatory at Potsdam.

NEW PUBLICATIONS.

BERGSTRAND, ÖSTEN. Recherches sur les coleurs des étoiles fixes. Upsala. 1909. 4°. 40 pp. Paper.

Encyclopédie Scientifique. Les observations méridiennes par F. BOQUET. Paris. 1909. 16°. Cloth.
I. Instruments et méthodes d'observation. 303 pp.
II. Corrections instrumentales et equations personelles. 342 pp.

HAYFORD, JOHN F. The figure of the earth and isostacy from measurements in the United States. Washington. 1909. 4°. 178 pp. Cloth.

Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg. La comète d'Encke 1891-1908 par O. BACKLUND. St. Petersburg. 1908. Folio. Paper.
Fascicule I. 92 pp.
Fascicule II. 59 pp.

NÖLKE, FR. Neue Erklarung des Ursprungs der Kometen. Bremen. 1909. 8°. 70 pp. Paper.

NUSL, FR., and JAN FRIC, JOSEF. Première etude sur les anomalies de réfraction. Prague. 1908. 8°. 10 pp. Paper.

Publications de l'Observatoire Engelhardt de l'Université Impériale de Kasan. Observations avec l'équatorial de 12-inch de Grubb. Recherches sur la vis micrométrique. Observations de 24 étoiles doubles faitès par M. M. GRATCHOF. Catalogue de 128 étoiles variables observées par M. V. BARANOF. Kasan. 1908. Folio. 83 pp. Paper.

Resultate des Internationalen Breitendienstes. Vol. III. TH. ALBRECHT and B. WANACH. Berlin. 1909. 4° 232 pp. Paper.

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NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

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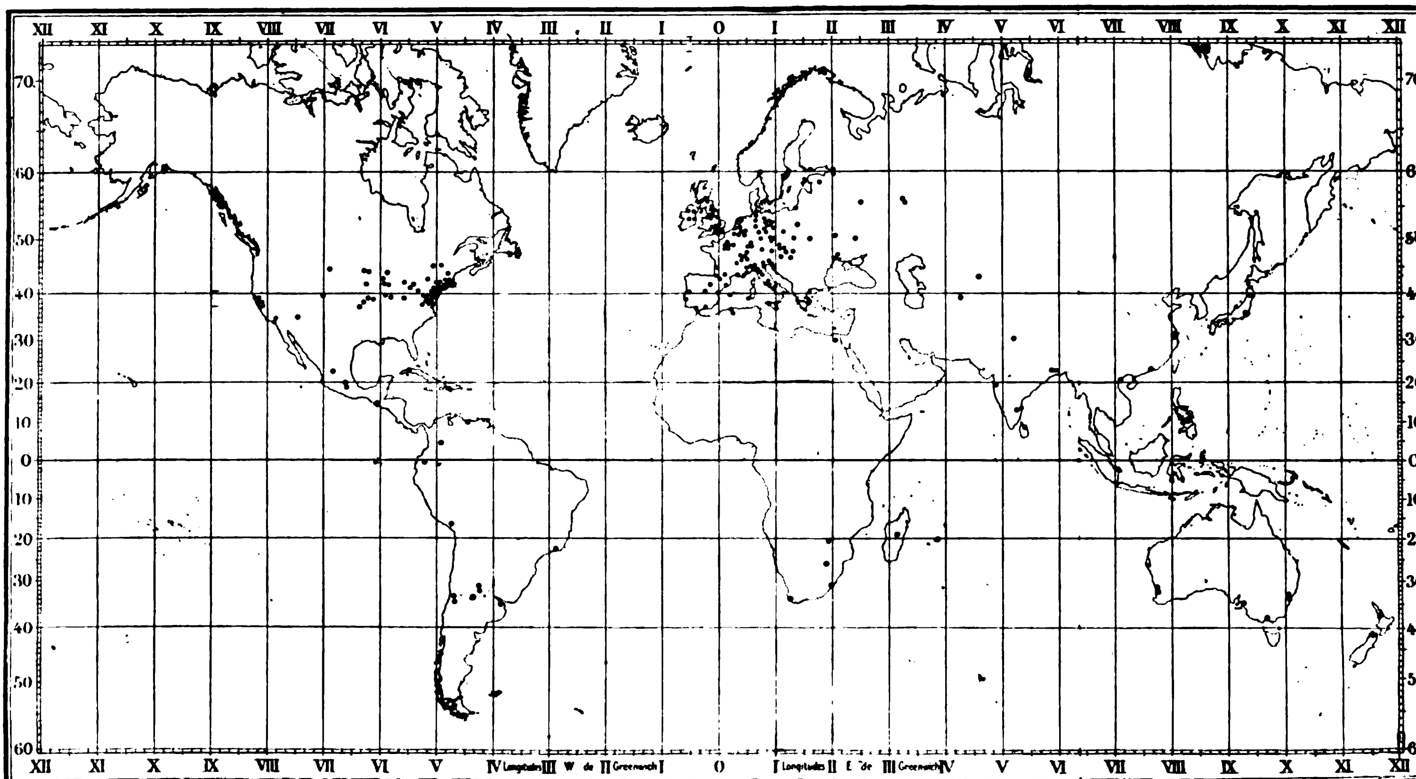

FIGURE I. DISTRIBUTION OF THE PRINCIPAL OBSERVATORIES OF THE WORLD

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XXI. San Francisco, California, December 10, 1909. No. 129

ASTRONOMICAL PROBLEMS OF THE SOUTHERN HEMISPHERE.

By Heber D. Curtis.

It is a natural result of the more recent development of the civilizations of the southern hemisphere that advances in the science of astronomy should likewise be less extensive than those made by the parent civilizations of the northern hemisphere. From the nature of the case, the southern hemisphere possesses relatively few astronomical records which can compare, in point of time, with those obtained for the northern skies during the last two centuries; and in the past, but to a less extent to-day, no small part of the progress made in mapping and studying the southern skies has been made by expeditions from the older foundations of Europe and America.

Probably the first observatory south of the equator which can be described as of a permanent character was that founded by Sir Thomas Brisbane in Paramatta, New South Wales, as a private observatory, in 1821; its period of activity extended over about ten years, and it was later incorporated with the Observatory of Sydney. An observatory was founded in Buenos Aires in 1822, but its period of activity was very short. Although the Observatory of the Cape of Good Hope was founded in 1820, its activity did not commence till 1829, the date of its completion; the extremely valuable and extensive work carried on here during the eighty years past give to it the unchallenged rank as the oldest permanent astronomical foundation in the southern hemisphere. At a later date we find the foundation of the Observatory of Santiago in 1856;

Melbourne, founded in Williamstown, Victoria, in 1853 and transferred to Melbourne in 1861; Adelaide, established in 1854; Córdoba, 1870; Arequipa in 1891, and others of more recent date. Among the early expeditions of a temporary character may be noted the visit of HALLEY to St. Helena in 1677; later we come to the appearance of the first large, systematic catalogue of the southern stars by LACAILLE as a result of his stay of four years at the Cape of Good Hope in the years 1751-55; the noteworthy investigations made at the same spot by Sir JOHN HERSCHEL from 1834 to 1838; the expedition sent to Santiago under charge of GILLISS in 1849; and others of more recent date to which attention will be called later.

The observatories in the southern part of the north temperate zone can extend their investigations in many lines of astronomical research to a distance of thirty degrees to the south of the celestial equator without great difficulty or loss of accuracy, but from this limit to the south pole we have a region amounting to about one fourth of the entire sky which, relatively to the northern skies, was almost as much a *terra incognita* seventy-five years ago as was Central Africa at the same date, and which to-day contains many virgin fields which offer rich returns to the exploring astronomer.

In the first great subdivision of astronomy, the astronomy of position, whose field is primarily the determination of the accurate positions of the fixed stars, the observed changes in these positions are so minute that the element of time becomes the most important factor to enable conclusions to be drawn from a given mass of observations as to the proper motions of the stars and the structure of the sidereal universe as a whole. Because of this relatively short time-factor since the earlier exact observations of the positions of the southern stars, the astronomy of precision of the southern hemisphere can not yet compete with the results from the northern heavens. Sir DAVID GILL has said, and there is doubtless no more competent authority to pronounce upon this point than he, that the state of our knowledge of the exact positions of the stars of the southern hemisphere is at least a century behind that of the northern hemisphere. Nevertheless, if we consider the results

already secured in the exact cartography of the southern skies, and take into consideration also the researches in this field at present well under way, we may safely reach the conclusion that the coming twenty years will render our knowledge of southern star positions very little inferior to those of the northern skies, always excepting, in this conclusion, the disadvantage arising from the lack of early observations, a lack which will necessitate the accumulation of results for many years before our knowledge of southern proper motions can equal that of the northern stars.

In this task of bettering our knowledge of exact star positions in the southern hemisphere it is doubtless superfluous to mention here the excellent work that has been done in the past and is now in progress at a number of southern observatories, especially the extensive results from Córdoba and the Cape of Good Hope. In 1865 the Astronomische Gesellschaft undertook the extensive task of mapping, by means of exact meridian observations, all the stars in the sky down to the ninth magnitude. This work for the northern hemisphere and for some distance south of the celestial equator is now practically completed, and the work is advancing favorably for the more southerly portions of the sky at the observatories of Madras, Melbourne, and the Cape.

One of the most important programs in connection with the astronomy of precision of the southern hemisphere is that inaugurated last year under the auspices of the Carnegie Institution of Washington. It has for its object the measurement of the accurate positions of about twenty-five thousand stars in the southern skies in accordance with the system of Professor Boss, of Dudley Observatory. The instrument employed is the meridian circle of the Dudley Observatory, which has been used in the past for exactly similar work in the northern skies. The constants, graduation errors, etc., of this instrument have been so thoroughly investigated that doubtless no more efficient instrument exists to-day for this class of work. By the use of the same instrument, the same system of reductions, and to a certain extent even the same observers, it seems probable that the results of this program will afford us a far more exact binding together of the northern and southern

skies in one homogeneous system than we possess to-day. The site has been selected at San Luis in the Argentine Republic. Professor TUCKER, of the Lick Observatory, is in charge of the Carnegie Observatory at San Luis, and recent advices state that the site seems to be a very favorable one for this class of work; it is hoped that the number of clear nights will average two hundred per year. The project involves about three years' work, and about seven observers and assistants are employed. Observations will be made throughout every clear night, "from sun to sun," with supplementary observations by day, and at this time the work of the observatory is doubtless in full swing.

In the years 1885-91, under the direction of Sir DAVID GILL, the Observatory of the Cape of Good Hope undertook an extensive photographic map of the southern skies, from declination — 19° to the south pole. The measurement of the positions of the stars on these plates was carried through by the disinterested and self-sacrificing labors of Professor KAPTEYN, and the publication in 1900 of the third and concluding volume of the great "Cape Photographic Durchmusterung" marked the completion of this monumental task. It contains the positions of 454,875 stars nearly to the tenth magnitude, and the positions are accurate to about one second of arc. It is an epoch-making work in the cartography of the southern heavens; in fact, until the completion of the "Astrographic Catalogue" no such complete and systematic photographic catalogue exists for the northern hemisphere. Naturally it can not compete, however, with the accuracy of the "Astrographic Charts"; those from Helsingfors, for example, having the small probable error of 0.″11 for the mean of two measured star images.

Without doubt, however, the greatest problem in the cartography of the southern skies which awaits the observatories of the southern hemisphere is the completion of their respective shares in the great photographic map of the heavens mentioned above, which was inaugurated at the International Conference in Paris in 1887. As is well known, this plan, in its entirety, involved the construction of a photographic map of the entire sky down to the fourteenth stellar magnitude, for which about twenty-two thousand plates were to be taken, and the total number of the stars registered on the plates would probably

reach twenty million. Supplementary to these charts the plan contemplated the publication of a great catalogue of perhaps two million stars down to the eleventh magnitude, based on plates of shorter exposure time. The task was apportioned among eighteen observatories in the two hemispheres. The observatories south of the equator which possess photographic equatorials of the uniform type adopted for the work are those at La Plata, Córdoba, the Cape, Santiago, Perth, Melbourne, and Sydney. It was proposed that the entire work be repeated in one hundred years. But so vast is the scope of this program that even in the northern hemisphere this project, whose value for the astronomy of position of the future can scarcely be over-estimated, has by no means made the progress anticipated for it at the time of its inception. Owing to the cost, only a few of the co-operating observatories have agreed to publish the great maps, and among southern observatories Perth has decided to take only the plates to the eleventh magnitude and to publish the resulting catalogue. Perth has taken all the plates in its zone, and has commenced the measures for the Catalogue. The section apportioned to the Cape of Good Hope is now nearly completed, both as to the taking of the plates and their measurement, and rapid progress is being made at Sydney, Melbourne, and Córdoba. Up to 1908 nothing had been done at La Plata or Santiago, though Dr. RISTENPART, recently appointed director of the National Observatory at Santiago, will make every effort for the prompt completion of the zone assigned to him; the work of taking the plates has already been begun under the direction of Dr. ZURHELLEN. It would seem that the publication of the costly maps might well be abandoned, for the plan adopted at Oxford of publishing only the co-ordinates of the stars would be far cheaper and fully as useful.

Excellent work has been done in determination of stellar parallax at the Cape of Good Hope, but the difficult field of work which has for its aim the determination of the distances of the stars by the heliometer or modern photographic methods is still practically untouched in the southern hemisphere. Parallaxes of only seventeen stars south of declination — 30° have been published, while north of this limit about three hundred

parallaxes have been determined, many of them a number of times, by different observers and different methods.

In the interesting field of double stars, as is well known, HERSCHEL discovered many systems in the southern skies, and modern observers, as INNES, TAYLOR, and others, have materially augmented this number. During the past decade Professors AITKEN and HUSSEY have been making a very complete and systematic search for such doubles in the northern celestial hemisphere, with the result that several thousand new doubles have been discovered, many of them of great interest. They have reached the conclusion that at least one in every eighteen stars brighter than the ninth magnitude is a visual binary system. To these results we must add the evidence of the spectroscope that one in every five or six of the stars thus far examined is a spectroscopic double, and we have facts whose importance it is scarcely possible to over-estimate in their bearing on our theories of stellar evolution. Such systematic researches for the discovery of visual doubles are most urgently needed in the southern skies to round out the program which these astronomers have now nearly completed for the northern portions of the heavens. In this regard there is no doubt that the southern sky offers one of the richest and most promising fields of research existing to-day. BURNHAM's great "Catalogue of Double Stars," recently published by the Carnegie Institution, includes 13,665 pairs of stars and extends to south declination 31°. This eminent authority estimates that a century must pass before sufficient data can be collected to make a similar catalogue necessary for the southern hemisphere. INNES's "Reference Catalogue of Southern Double Stars" [1] contains 2,191 pairs between the equator and the south pole, but of this number about 925 are between the equator and BURNHAM's southern limit, nearly all of which have been discovered by observers in the northern hemisphere. A comparison of the number remaining, south of —31°, with the results from the northern skies will show clearly that there may well be two thousand double stars brighter than the ninth magnitude at present awaiting discovery in the southern hemisphere, to say nothing of the need for additional researches on the pairs already known.

[1] Cape Annals, Vol. II, part II, 1899.

During the past ten years systematic observations have been made at six special stations in the northern hemisphere to study the small oscillations of the axis of the earth known as the variation of latitude. These stations are located at Mizusawa, Japan; Tschardjui, Asiatic Russia; Carloforte, Italy, and at Gaithersburg, Maryland; Cincinnati, Ohio, and Ukiah, California; and are all situated almost exactly on the parallel of north latitude 39° 8′. In 1905 the association which has this research in hand, Das Centralbureau der Internationalen Erdmessung, decided to extend this series of observations to the southern hemisphere, and the plans at first contemplated three stations: in Sydney, Australia; Capetown, Africa; and Santiago, Chile. It was pointed out, however, by Dr. HELMERT that better results could be secured, as far as the evaluation of the so-called Kimura-term in the latitude equation was concerned, by two stations placed as exactly as possible on opposite sides of the earth. Accordingly, after correspondence with authorities in Australia and the Argentine Republic, two sites were chosen in 1905 which satisfy this condition, and are, in addition, admirably situated as regards climatic advantages. Both are in south latitude 31° 55′ 15″, and differ 179° 36′ in their longitudes. The Australian installation is in charge of Dr. HESSEN, formerly of Berlin, and is located at Bayswater, West Australia, about four miles from Perth, the capital. The Argentine station is under the direction of Dr. LUIGI CARNERA, formerly occupied in similar observations at Carloforte, and is located at Oncativo, about forty-five miles from Córdoba.

Both of these stations commenced observations in 1906, and the work has been prosecuted with great energy since that date.[1] The results thus far secured are enabling us to draw more accurate conclusions with regard to these supplementary, exceedingly minute movements of the Earth's axis.

The formula for the variation of latitude is ordinarily expressed by the equation

$$\phi - \phi' = x \cos \lambda + y \sin \lambda + z,$$

where x and y are the components of the variation in the planes of zero longitude and that perpendicular to this, while the

[1] The observations at Bayswater were discontinued in January, 1909; the station at Oncativo has been taken over by the Government of the Argentine Republic.

term z, called the Kimura-term from the Japanese astronomer who suggested its introduction, denotes that part of the variation which is common to all the stations, corresponding to an apparent movement of the center of gravity of the earth toward one or the other pole. The results from the northern stations have revealed the interesting fact that the value of z is periodic, with a period of one year, reaching its zero values about March 9th and September 12th, and its maximum and minimum values on June 10th and December 10th, these points coming, then, about ten days before the solstitial points. The preliminary results from the southern stations coincide almost exactly with those from the northern stations with respect to the magnitudes of x and y, and show, in addition, that the value of the z-term is of the same magnitude and algebraic sign as that derived from the northern results. This z-term is very small, oscillating only 0."046 on each side of the mean, which, if real, would correspond to a movement of the center of gravity of the earth of about four and a half feet toward the north or the south pole. The temptation is very strong to seek a meteorological explanation for this small shift of the plane of the equator. The accumulation of snow and ice at one pole, together with the corresponding diminution at the other pole due to the melting in the summer season, would be perhaps sufficient to explain the shift, but, if this were the true and only explanation, it is difficult to see why the maxima and minima do not follow the solstitial points by a considerable interval of "lag," instead of preceding them by about ten days.[1] Moreover, the quantities involved are so extremely minute, such transcendental care is necessary in arranging and making the observations, and such pains to exclude in the investigation all possible sources of systematic error, that astronomers are by no means in accord as to the real existence of the z-term. BISKE has shown that a variation similar to that afforded by the z-term could arise as a result of inaccuracies in the adopted value of the solar nutation, and that future progressive changes in this value could result from similar slight errors in the adopted value of the lunar nutation. Quite recently Professor HIROYAMA,

[1] Later studies seem to indicate that the maxima and minima in the z-term are slowly shifting.

of Tokio, has subjected the results of the first four years of the latitude variation results to a careful analysis, and reached the conclusion that the z-term is probably a result of errors which may be classified as instrumental. He did not include in his researches, however, the results from the southern stations.

Probably no more marked case of modern specialization in the science of astronomy, no more fitting example of minute and careful analysis, nor any better illustration of the mutual interdependence of fields of investigation apparently widely separated, can be found than this same subject of the variation of latitude. Long since, EULER, from purely mathematical considerations with regard to a rotating spheroid, showed that the axis of the earth should be subject to a minute oscillation, with a period of 305 days. In 1890-91 Professor KÜSTNER announced that this prediction had been confirmed by observation, but that the period was about 427 days. So minute is the movement that the poles shift from their mean position by less than thirty feet. Eight special observatories have been established, six in the northern hemisphere and two in the southern, and experienced observers are carefully accumulating the observations for the further study of this variation, determining from observations of the stars a periodic movement of the positions of the poles of the earth only a little greater than the distance from one wall of their small observatories to the other, and even showing, with some probability, that the earth's center of gravity oscillates once a year a distance of only a little over four feet toward one pole or the other. From these results DARWIN, HOUGH, LARMOR, and others have undertaken the investigation of the difference between the observed period of 427 days and that of 305 called for by theory, finding the explanation in the slight yielding of the earth, and have deduced the result that the earth, as a whole, must possess an effective rigidity a little greater than that of steel. In confirmation of these results, tidal students have found evidences, though very slight, of a minute tide with a period of 430 days. And in still another field these results may possibly prove of interest. No less an authority on earthquakes than Professor MILNE has expressed

the opinion that earthquakes are more frequent at those epochs when the axis of the earth is farthest from its mean position, though this theory is not accepted by most seismologists.

In the wide field of stellar photometry, a very large proportion of our knowledge of the southern stars comes from the results of the Harvard photometric expeditions and particularly from its station at Arequipa, Peru. Through the visual results secured at Córdoba, the photographic magnitudes as given by the Cape Photographic Durchmusterung, and the long series of exact visual estimations made with the meridian photometer at Arequipa, we may say that, except in certain special studies on the fainter stars, the state of our knowledge of the relative brilliancy of the stars of the southern hemisphere is not inferior to that of the northern hemisphere.

From this station, too, has come far the largest proportion of what is known to-day with reference to the variable stars in the more southerly regions of the sky. Epoch-making in this branch is the discovery by Professor BAILEY of a very large number of variable stars in clusters. The Magellanic Clouds and other clusters in the southern hemisphere have alone given about two thousand new variable stars; the determination of the periods of all these and the study of the peculiarities in their variation will in itself furnish work for many years to come. Much remains to be done as well on the brighter variable stars of the southern hemisphere.

Through the excellent work at Arequipa, also, Harvard's extensive spectrographic surveys have been extended to the south pole. While it is certain that future studies with spectrographs of higher dispersion will bring forth many new facts with regard to stellar constitution, there is no doubt that Harvard's extensive surveys of the entire sky in the photometric and spectrographic fields will for decades be to the astrophysicist what the Bonn Durchmusterung has been to the worker in the astronomy of position.

As in the surveys just mentioned, the spectrograph was at first employed solely to determine the constituent elements of the Sun and the stars, but the application of the Doppler-Fizeau principle to the determination of a star's velocity in the line of sight from its spectrum has opened up to astronomy

a field so vast that we scarcely dare to-day even to demark its boundaries. Few are the fields of astronomical research where the work in radial velocities is not making itself felt, and to-day we are furnished with the interesting spectacle of the oldest astronomy of position and the newer astronomy of the spectrum drawing closer and closer together for the solution of problems of sidereal structure. In order to determine the motion of our Sun through space many analyses have been made of the minute proper motions of the stars across our line of vision, but all such determinations are subject to some uncertainty because of the fact that the true distances of the stars whose proper motions are used in the analysis are, in general, very imperfectly known. On the other hand, the spectrograph gives us the velocity of a star in the line of sight, a velocity which, in stars possessing good spectral lines, is accurate within a few tenths of a kilometer per second, and which is entirely independent of the distance of the star from our system. For this reason it should be possible to determine from the radial velocities of a considerable number of stars well distributed over the entire sky a much more accurate value of the amount and the direction of the movement of the solar system through space.

For a complete solution of this problem, at which Dr. Campbell and his associates have been working during the past fifteen years, it was necessary that radial velocities he secured for the stars in the southern hemisphere. This need was laid before Mr. D. O. Mills, who, in 1902, generously gave the funds necessary for the installation on Mount San Cristóbal, Santiago, Chile, of a 37-inch reflecting telescope with the necessary spectrographic equipment, and in 1905 advanced further funds to continue the southern work for five years longer.

Up to date about 6,200 spectrograms have been taken at Mt. Hamilton and 2,700 by the D. O. Mills Expedition at Santiago, on nearly 1,400 stars. The northern portion of the program is nearly completed, and two years more should see the southern portions of the work essentially finished, though decades could well be used in investigating the "by-products" which have appeared in the course of the work, and other

decades for the much needed extension of these researches to fainter stars. To give one instance only, at the Santiago station alone forty-eight spectroscopic binaries have been announced up to May, 1909, and to work up these binary systems adequately and compute their orbits would necessitate at least three years' work. One in every five or six of the northern stars examined has proved to be a binary, and nearly one in five of the stars observed by Professor WRIGHT during the first two years and a half of the work of the D. O. Mills Expedition. The discovery of so many spectroscopic binaries has greatly complicated the problem of determining the solar motion; moreover, several other complexities have of late been added to the analysis of the results. Recent investigations of the proper motions of the stars made by KAPTEYN, EDDINGTON, DYSON, SCHWARZSCHILD, and others, have shown that our universe is probably complex rather than homogeneous in respect to its structure, for there seem to be at least two fairly well marked directions of motions among the stars as a whole. Moreover, MONCK and KAPTEYN have pointed out that a considerable majority of stars possessing marked proper motions belong to those spectral types which show numerous lines of various elements, while the hydrogen and helium stars are relatively fixed in space. In connection with these facts a further complexity is brought in on the spectroscopic side through the unfortunate circumstance that it is not possible to derive accurate velocities for many of the hydrogen and helium stars, because of the wide and hazy character of their spectral lines. A simple solution will then perhaps be insufficient, on the assumption that all the velocities arrange themselves according to the probability curve; it would seem that a satisfactory conclusion can only be reached by a very careful combination of spectrographic results with due regard to all that the astronomy of position can give us with reference to "star-drift," proper motions, and variation of proper motion with type of spectrum.

Work on the determination of radial velocities has recently been inaugurated at the Observatory of the Cape of Good Hope, so that these two observatories, that at the Cape, and the D. O. Mills Expedition, have to themselves this rich and

still only partly explored field, while in the northern hemisphere some ten observatories are at work on problems more or less allied to the determination of radial velocities.

In Figure I are shown the location of the principal observatories of the world; the cut is that given by STROOBANT in *Les Observatoires Astronomiques et les Astronomes,* Bruxelles, 1907, with the addition of a few recently established stations. The map shows, better than any description or tabulation, the overwhelming disproportion in the number of astronomical foundations in the northern and southern hemispheres.

Sufficient has been said to point out the great richness of the skies of the southern hemisphere as a field for the working astronomer, and note has been made of some of the lines of work in which there are great untouched regions awaiting the explorer. Numerous other points in which there is need for work in southern skies could easily be pointed out. Much work still remains to be done by those who are not possessed of powerful instruments in the study of the brighter variable stars and meteor radiants. Excellent photographs have been made with the Bruce Refractor at Arequipa, but the field of southern nebular photography with reflecting telescopes is almost untouched as yet, and there is no more urgent need for the astronomy of the southern hemisphere than the establishment of a large reflector to continue for the southern skies the work done by ROBERTS, KEELER, PERRINE, and others on the northern nebulæ and clusters, for the study of faint variable stars, for parallax investigations, and many other allied lines of research. A program of nebular photography has been inaugurated with the new reflector at Helwan, Egypt; its southern limit, however, will extend only to —40°. The day must come, also, when there shall be established at some favorable point in the southern hemisphere a large solar observatory to carry on solar studies and investigations of the Sun's constant of heat in the southern summer season, thus supplementing the work of the northern solar observatories.

Above all, so few are the workers in this southern field compared with the men and the instruments attacking the problems of the northern skies, that some scheme of co-operation among southern observatories seems imperative, each one

to devote its attention to some one line of work or some definite zone. Professor COOKE, of Perth, has recently pointed out the disadvantages arising from scattered and unsystematic observations in meridian circle work, and has announced that for the future all the efforts of Perth Observatory in determining stellar positions will be concentrated upon the zone from south declination thirty-one to forty-one degrees. Some such plan of co-operation and delimitation seems essential for the future progress of astronomy, and more particularly for the astronomy of the southern hemisphere; as Professor KAPTEYN has pointed out, the scope of this science to-day, with its millions of isolated units demanding study, is too vast for the combined efforts of all the observatories of the world, and he has accordingly suggested the well-known plan of limiting future studies to certain relatively small "selected areas," a plan which promises to be the best method of extending our finite knowledge in a realm that is practically infinite.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1910.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter...Jan.	3, 5^h 27^m A.M.		Last Quarter..Feb.	2, 3^h 27^m A.M.	
New Moon..... "	11, 3 51 A.M.		New Moon.... "	9, 5 13 P.M.	
First Quarter... "	18, 2 21 A.M.		First Quarter.. "	16, 10 32 A.M.	
Full Moon..... "	25, 3 51 A.M.		Full Moon.... "	23, 7 36 P.M.	

The Earth is in perihelion January 1st, 3^h A.M., Pacific time.

Mercury is an evening star until January 26th, 1^h A.M., when it passes inferior conjunction and becomes a morning star, remaining a morning star until early April. During the first half of January it will be a comparatively easy object for naked-eye view in the twilight soon after sunset, remaining above the horizon more than an hour, and at the time of greatest east elongation, January 10th, nearly an hour and one half after sunset. The greatest east elongation is rather a small one, as it occurs only eight days before the time of perihelion, and this makes

rather a short period of visibility. After greatest elongation it moves rapidly toward inferior conjunction and then rapidly away from the Sun westward. It reaches greatest west elongation on February 19th, 26° 33′, a distance from the Sun not much less than the maximum, as it is then only eleven days from aphelion. During the latter half of February it may be seen under favorable weather conditions in the early morning twilight, as it rises somewhat more than an hour before sunrise. On February 27th it is in conjunction with *Venus*, the latter planet being 9° 18′ north of the former.

Venus is an evening star throughout January, passes inferior conjunction with the Sun on the morning of February 12th, and remains a morning star until it reaches superior conjunction on November 26th. On January 1st it sets about three and one-half hours after sunset. This interval diminishes to about three hours by the middle of the month, and at the end of the month it is only an hour and one half. It can be seen as an evening star for only a few days in February, as it rapidly nears inferior conjunction. By February 20th it rises more than an hour before sunrise and this interval is increased by half an hour before the end of the month. The period of invisibility on account of proximity to the Sun is much less than it usually is, for the reason that the planet passes the point in its orbit farthest north from the ecliptic on February 26th, and at the time of inferior conjunction is 8° north of the Sun. It is barely possible that it may be seen both as evening and morning star on the same day. During January the planet will be very bright, reaching its maximum at the end of the first week of the month. For some weeks it will be bright enough to be seen in full daylight by the naked eye.

Mars is still in good position for observation, as it remains above the horizon until after midnight throughout the two months' period, and may be easily seen in the southern or southwestern part of the heavens on any clear evening. It moves 34° eastward and 12° northward among the stars from the eastern part of *Pisces* through *Aries* to the western part of *Taurus*. On January 1st its distance from the Earth is about the same as the Earth's mean distance from the Sun, but the distance is increasing very rapidly, and by the end of Feb-

ruary it is more than fifty per cent greater than it was in early January. Its brightness is of course greatly diminished from that it had in the early autumn of 1909, being on January 1st less than one sixth of the brightness at opposition, and it will lose more than half of this by the end of February. But it will still be as bright or brighter than a standard first magnitude star; and there will not be the slightest difficulty in recognizing it, as it is in a region where there are no bright stars, and its peculiar ruddy color will also aid in identifying it.

Jupiter rises shortly after midnight on January 1st, and at about 8^h 30^m P.M. on February 28th. During the latter part of the period it will be in fair position for observation in the southeastern sky late in the evening. It is in the western part of the constellation *Virgo* and moves about one degree eastward until January 30th, and during February retogrades, moves westward, about the same amount.

Saturn is very close to *Mars*, about 3° south, on January 1st, setting not long after midnight, but its eastward motion among the stars is comparatively slow, and the planets rapidly separate. By the end of February *Saturn* sets shortly after 9 P.M. It is in the constellation *Pisces* and moves about 4° eastward and northward during the two months.

Uranus passed conjunction with the Sun in December, 1909, and is a morning star, but during the greater part of the period is too near the Sun to be seen. At the end of February it rises about 2^h 30^m A.M. It moves about 3° eastward in the constellation *Sagittarius* during the two months.

Neptune comes to opposition with the Sun on January 8th, and is then above the horizon throughout the entire night; but it is too faint to be seen without a telescope. It moves westward slowly in the constellation *Gemini*.

BY-LAWS
OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC.

ARTICLE I.

This Society shall be styled the ASTRONOMICAL SOCIETY OF THE PACIFIC. Its object shall be to advance the Science of Astronomy, and to diffuse information concerning it.

ARTICLE II.

This Society shall consist of patrons, active members and life members, to be elected by the Board of Directors.

1. Persons who render distinguished services to the Society may be designated as patrons of the Society. The consenting votes of eight members of the Board of Directors shall be necessary for election to this status. Such election shall carry with it election to life membership in the Society and the privileges attached thereto.

2. Active members shall consist of persons who shall have been elected to membership and shall have paid their dues as hereinafter provided.

3. Life members shall consist of persons who shall have been elected to life membership and shall have paid $50 (fifty dollars) to the Treasurer of the Society.

4. A certain number of observatories, academies of science, astronomical societies, institutions of learning, etc., not to exceed one hundred, shall be designated by the Board of Directors as Corresponding Institutions, and they shall receive the Publications of this Society in exchange or otherwise.

ARTICLE III.

At each annual election there shall be elected a Board of eleven Directors, and a Committee on Publication, consisting of three members. The officers of this Society shall be a President, three Vice-Presidents, two Secretaries, and a Treasurer. The Directors shall organize immediately after their election, and elect from their number the officers of the Society. They may also appoint a Librarian, and such other assistants as may

be required. The Directors shall fill by appointment any vacancies which may occur after the annual election.

The Library of the Society shall be kept in San Francisco, and shall be open to the use of all the members.

ARTICLE IV.

The President, or, in his absence, one of the three Vice-Presidents, or, in the absence of both the President and the Vice-Presidents, any member whom the Society may appoint, shall preside at the meetings of the Society. It shall be the duty of the President to preserve order, to regulate the proceedings of the meetings, and to have a general supervision of the affairs of the Society. The President is, *ex-officio,* a member of all Committees of the Board of Directors.

ARTICLE V.

The Secretaries shall keep, and have the custody of, the records; they shall have the custody of all other property of the Society, excepting the money thereof; they shall give timely notice of the time and place of meetings; they shall keep in books a neat and accurate record of all orders and proceedings of the Society, and properly index them; they shall conduct the correspondence of the Society; they shall preserve and index the originals of all communications addressed to the Society; and keep a copy of all their letters, properly indexed; and they shall prepare for publication an accurate summary of the transactions of the Society at each of its meetings.

ARTICLE VI.

The Treasurer shall receive and deposit in such bank as may be designated by the Directors, to the credit of the Society, all donations and bequests of money and all other sums belonging to the Society. He shall keep an account of all money received and paid by him, and at the annual meetings shall render a particular statement of the same to the Society. Money shall be paid by him only on the written order of the Finance Committee of the Board of Directors. He shall give such bonds as may be required by the Board of Directors.

ARTICLE VII.

Candidates for active or life membership may be proposed by any member of the Society to either of the Secretaries, in writing. A list of such candidates shall be certified to the Board of Directors by the Secretaries at each of their meetings, in writing. A majority (not less than three) of the Directors present at any such meeting shall be required for election.

ARTICLE VIII.

Each active member shall pay as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three-fourths only of such dues; when elected during the third quarter, he shall pay one-half only of such dues; when elected during the last quarter, he shall pay one-fourth only of such dues; provided, however, that one-half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. No one shall be deemed an active member, or receive a diploma, until he has signed the register of members, or accepted his election to membership in writing, and paid his dues for the current year. Any member may be released from annual dues by the payment of fifty dollars at one time, and placed on the roll of life members by the vote of the Board of Directors. Any failure on the part of a member to pay his dues within six months after the time the same shall become payable, may, at the discretion of the Board of Directors, be considered equivalent to a resignation.

ARTICLE IX.

The annual meeting of this Society shall be held on the last Saturday in March, at eight o'clock P. M., at the rooms of the Society in San Francisco; and meetings shall be held for the ordinary transactions and purposes of the Society, as follows:—

A meeting shall be held in the library of the Lick Observatory at a suitable hour on the last Saturday of August; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M., on the last Saturdays of January, March, June and November; but it shall be within the discretion of the President to designate other places of meeting, in San Francisco or vicinity, for the meetings of January, June and November, whenever, in his opinion, such change will be to the advantage of the Society.

A special meeting may be called by the President, or, in his absence or disability, by one of the Vice-Presidents, or, in the absence or disability of both the President and the Vice-Presidents, by the Secretary, on the written requisition of ten active or life members; and the object of such meeting shall be stated in the notice by which it is called.

The annual election shall be held on the day of the annual meeting, between the hours of 8:15 and 9 P. M.

No member shall be permitted to vote at any meeting of the Society who has not paid all his dues for past and current years. There shall be no voting by proxy.

ARTICLE X.

Fifteen active or life members shall be a quorum for the transaction of business.

ARTICLE XI.

No papers or manuscripts shall be published by the Society without the consent of the Directors. Any motion to print an address, or other paper read before the Society, or any other matter belonging to the Society, shall be referred to the Committee on Publication, who shall report to the Directors. The Committee on Publication may make suggestions to the Directors, from time to time, with reference to the publication of such papers as in their judgment should be published by the Society; and this Committee shall have the care, direction and supervision of the publication of all papers which the Directors may authorize to have published.

Members of the Society shall receive all the Publications of the Society free of charge.

ARTICLE XII.

This Society may, by a vote of a majority of all its active and life members, become a branch of an American Astronomical Society, should one be formed.

ARTICLE XIII.

It shall be the duty of the Directors, in case any circumstances shall arise likely to endanger the harmony, welfare or good order of the Society, to call a special meeting of the Society; and if, at such meeting, after an examination of the charges, and hearing the accused, who shall have personal notice of such proceedings, it shall be proposed that the offending member or members shall be expelled, a vote by ballot shall be taken, and if two thirds of the members present vote in favor thereof, the offending member or members shall be expelled.

ARTICLE XIV.

The Directors shall meet half an hour before the stated time of each regular meeting, and at such other times as they may appoint. The President, or, in his absence, any one of the Vice-Presidents, may call special meetings of the Board of Directors at any time. Notice of the time and place of such meeting shall be given by the Secretaries, by depositing in the post-office at San Francisco a notice of the time and place, addressed to each Director personally, at his last known place of residence, with the postage thereon prepaid, six days before the time of meeting.

ARTICLE XV.

The By-Laws may be amended at any time by a consenting vote of nine members of the Board of Directors at any duly called meeting thereof.

ARTICLE XVI.

In order to increase the usefulness of the Society, any groups of its members residing in the same neighborhood (except in the City and County of San Francisco, State of California,) are authorized to form local organizations which shall be known as "The ——— Section of the Astronomical Society of the Pacific."

No Section shall be formed except by the consent of the Board of Directors of the parent Society.

The proceedings of such Sections may be printed in the Publications of the Astronomical Society of the Pacific, either in full or in abstract, and the parent Society shall not be in any way responsible for publications made elsewhere.

No person not a member of this Society in good standing shall be eligible to membership in a Section, nor shall membership in a Section interfere in any way with the status of the person as a member of this Society.

The special expenses of each Section shall be borne by the group of members composing it, and this Society shall not be liable for any debts incurred by any Section.

STATUTES FOR THE BESTOWAL OF THE BRUCE MEDAL OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

I. A medal is founded by Miss CATHERINE WOLFE BRUCE, of New York, to be given, not oftener than once a year, for distinguished services to astronomy. The medal is international in character, and it may be awarded to a citizen of any country, and to a person of either sex.

II. The cost of the medal is to be met from the interest of the *Bruce Medal Fund* of $2500. The capital of this fund is not to be impaired. Unexpended interest is to be added to the capital to become an integral part thereof.

III. The medal is to be of gold. The *obverse* is to bear the Seal of the Astronomical Society of the Pacific. The *reverse* is to bear an inscription as follows: THIS MEDAL, FOUNDED A. D. MDCCCXCVII, BY CATHERINE WOLFE BRUCE, IS PRESENTED TO ....FOR DISTINGUISHED SERVICES TO ASTRONOMY .... (date in years).

IV. The Bruce Medal is not to be given twice to the same individual.

V. On the first of September of every year one of the Secretaries of the Astronomical Society of the Pacific is to

address an official letter to the Director of each of the following Observatories, namely:—

The Harvard College Observatory,	The Observatory of Berlin,
The Lick Observatory,	The Observatory of Greenwich,
The Yerkes Observatory,	The Observatory of Paris,

enclosing the statutes relating to the Bruce Medal, and requesting each of the six Directors just named to nominate not to exceed three Astronomers worthy to receive the medal for the ensuing year.*

The replies of the said Directors are not to be communicated by the Secretary to any person until the first of November, when a list containing the names of the Astronomers so nominated is to be certified, in writing, by the Secretary, to each of the eleven Directors of the Astronomical Society of the Pacific; and a special meeting of the Directors called for the last Saturday in November, at 2 P. M. At that meeting these Statutes are to be read; and the original letters from the Directors of the Observatories are to be submitted by the Secretary, and afterwards sealed in an envelope and deposited in the archives of the Society, not thereafter to be opened except by a formal resolution of the Directors, passed at a regular meeting. All such letters and nominations are to be regarded as confidential by all who are knowing to them.

VI. The Directors of the Astronomical Society of the Pacific, at the special meeting aforesaid, may vote in person or by written proxy.

The medal is not to be awarded unless the votes of at least six Directors are cast at this meeting. It may be awarded to any individual named in the list certified by the Secretary by the consenting votes of six Directors; or, the consenting votes of six Directors may order that no award shall be made for the ensuing year.

The award of the medal, if made, is to be for the calendar year commencing with the January after the meeting at which the award is made; and on January 1st one of the Secretaries

* In response to a request made by one of the nominating observatories, the Board of Directors of the Society has construed the provision in Article V of the Statutes, referring to "astronomers worthy to receive the medal for the ensuing year," to cover services rendered during the life-time of the nominee.

of the Astronomical Society of the Pacific is to officially notify the recipient of the award, and on receiving a letter of acceptance, is to transmit the medal, engraved with the name and year. The name of the recipient of the medal is not to be made public until after the receipt of a letter of acceptance.

The President of the Astronomical Society of the Pacific, in his address at the annual meeting of the Society in March is to announce the award and the reasons for making it.

VII. It is competent for the eleven Directors of the Astronomical Society of the Pacific, by a unanimous vote, and not otherwise, to substitute for any one of the Observatories named in Article V some other Observatory. It is desirable, though not essential, that three of the Observatories aforesaid shall be American and three Foreign.

Not more than one such substitution is to be made in any single calendar year.

RULES RELATING TO THE COMET MEDAL OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

I. A medal of bronze is established, as a perpetual foundation, to be given for the discovery of comets, as follows:—

The medal is to bear on the *obverse* side the effigy of a bright comet among stars, with the legend, "ASTRONOMICAL SOCIETY OF THE PACIFIC," around the border; and on the *reverse* the inscription, "THIS MEDAL FOUNDED IN 1890 BY JOSEPH A. DONOHOE, IS PRESENTED TO .... (the name of the discoverer) TO COMMEMORATE THE DISCOVERY OF A COMET ON .... (the date)."

It is to be understood that this medal is intended solely as a recognition of merit, and not as a reward.

II. The medal will be given to the actual discoverer of any unexpected comet.

III. The discoverer is to make his discovery known in the usual way, and, in order to simplify the work of the committee, which, in certain cases may be called upon to consider the merits of several independent discoveries of the same object,

he should also address a letter to the Director of the Lick Observatory, which should state the exact time of the discovery, the position of the comet, the direction of its motion (when this can be determined), and the physical appearance of the object.

No application for the bestowal of the medal is required. The letters received from discoverers of comets will be preserved in the records of the Lick Observatory. Cable telegrams to the Lick Observatory are to be addressed to "Astronomer, San Francisco."

IV. All communications will be referred to a committee consisting of the Director of the Lick Observatory, *ex officio*, and of two other persons, members of the Astronomical Society of the Pacific, who are to be annually appointed by the Board of Directors. The decisions of this committee are to be final upon all points relating to the award of the medal. The committee will print an annual statement of its operations in the Publications of the Society.

Under ordinary circumstances the comet medal will be awarded within two months after the date of the discovery. In cases of doubt a longer period may elapse. The medal will not be awarded (unless under the most exceptional circumstances) for the discovery of a comet until enough observations are secured (by the discoverer or by others) to permit the calculation and verification of its orbit.

V. This medal is to be a perpetual foundation from and after January 1, 1890.

NOTICE TO MEMBERS.

In order to facilitate correspondence between the officials of the Society and its members and to insure the proper delivery of its Publications, all members are respectfully requested to notify the Secretary of any changes in post-office address.

Communications addressed to the undersigned will have prompt attention.

D. S. RICHARDSON,

Secretary Astronomical Society of the Pacific,
Room 748 Phelan Building, San Francisco, Cal.

NOTES FROM PACIFIC COAST OBSERVATORIES.

The Orbits of ϵ *Hydræ*, AB, and of β 883.

By graphical methods orbits have been computed of AB of ϵ *Hydræ,* whose α for 1900.00 was $8^h\ 41^m$ and $\delta + 6° 47'$, and of β 883, whose α for 1900.00 was $4^h\ 5^m\ 40^s$ and $\delta + 10° 54'$.

The elements of ϵ *Hydræ* differ somewhat in node and inclination from those by Dr. Aitken in *Lick Observatory Bulletin* No. 36, but they fully represent the observations.

The elements of β 883 represent the observations as well as do those of Schoenberg, given in *Astronomische Nachrichten*, **178**, p. 187, 1908, and about as well as those of See, given in *Monthly Notices,* **58**, p. 566, 1908. The differences in the three sets of elements are due mainly to the difference in the weights given the observations. These differences may be regarded as a measure of the uncertainty still attaching to our knowledge of the true orbit of this system.

The elements of AB of ϵ *Hydræ* are:—

$$T = 1901.11$$
$$P = 15.63 \text{ years}$$
$$e = 0.69$$
$$a = 0''.267$$
$$\Omega = 122°.7$$
$$i = 63°.29$$
$$\omega = 259°.46$$
$$\mu = 23°.032$$

THE EPHEMERIS.

Date.	θ	p	Date.	θ	p
1909.825	200°.96	0''.20	1915.825	294°.29	0''.15
1910.825	214 .65	0 .19	1916.825	42 .51	0 .04
1911.825	229 .59	0 .19	1917.825	124 .91	0 .17
1912.825	244 .79	0 .19	1918.825	137 .75	0 .23
1913.825	260 .03	0 .19	1919.825	146 .74	0 .25
1914.825	275 .57	0 .18	1920.825	155 .93	0 .25

My elements of β 883 are (with those by SCHOENBERG and by SEE for comparison):—

	MISS BROWN	SCHOENBERG	SEE
$P=$	16.6 years	16.90 years	16.6 years
$T=$	1907.2	1907.39	1907.33
$e=$	0.42	0.42	0.47
$a=$	0".22	0".21	0".24
$\Omega=$	22°.0	54°.4	33°.5
$i=$	38°.72	16°.08	35°.7
$\omega=$	207°.96	172°.95	197°.3
$\mu=$	22°.401		

THE EPHEMERIS.

Date.	θ	ρ	Date.	θ	ρ
1909.84	343°.42	0".19	1915.84	47°.36	0".30
1910.84	10 .69	0 .21	1916.84	56 .35	0 .28
1911.84	12 .17	0 .26	1917.84	61 .68	0 .27
1912.84	21 .92	0 .28	1918.84	79 .33	0 .23
1913.84	32 .56	0 .30	1919.84	95 .89	0 .20
1914.84	39 .09	0 .30	1920.84	118 .04	0 .17

FLORENCE BROWN.

THE BRIGHTNESS OF THE SATELLITES OF *MARS*.

The statement is made in some recent textbooks on astronomy that *Phobos* and *Deimos,* the two small satellites of *Mars,* can be seen only with very large telescopes and *then only by screening the light from the planet.* A series of measures of these two satellites was made by me in September and October of the present year, and this gave me the opportunity to confirm my impression of the error of this statement. A large telescope is indeed required to show these tiny bodies, and they can be seen only when *Mars* is comparatively near opposition, but under good conditions it is then unnecessary to protect the eye from the light of the planet. *Phobos,* the inner satellite, is very decidedly the brighter of the two, and can be seen, with the 36-inch, in the full light of *Mars* when less than 3" from the planet's limb. *Deimos* is fainter, and is a difficult object in the planet's light when 10" from the limb. At distances greater than these limits both satellites are readily visible without screening the light from *Mars,* when the seeing is good. My estimates make *Phobos* fully six times as bright as *Deimos* when at the same distance from the planet: that is, about two stellar magnitudes brighter.

November 19, 1909. R. G. AITKEN.

December Observations of Halley's Comet.

Halley's Comet was observed with the 36-inch refractor on the nights of December 14th, 15th, 17th, and 18th. The measures of position show that the correction to Father Searle's ephemeris was then about $+ 5^s$ in right ascension and about $+ 0'.2$ in declination. The comet appeared to be nearly round, the coma being $1' \pm$ in diameter, with a sharp nucleus. The halo around the comet extended over an area nearly 15′ in diameter, and was decidedly brighter and somewhat more extended on the following side. No other evidence than this could be found of a tail. The comet was estimated to be of the tenth magnitude. It was easily detected with the 3-inch finder of the 12-inch telescope on the night of December 10th.

December, 1909. R. G. Aitken.

Note on Halley's Comet.

Halley's Comet is increasing rapidly in brightness. In the middle of December it was an easy object in a 6-inch telescope, and could be made out in a 3-inch. At this time the effective magnitude of the comet as a whole must have been about the tenth magnitude. The computed brightness of the comet on December 16th, according to Crommelin, was $13^m.0$ on the assumption that the brightness varies as $\frac{1}{r^2 \Delta^2}$, and $12^m.0$ on the assumption that the brightness varies as $\frac{1}{r^4 \Delta^2}$. From this it will be seen that the comet's increase in brightness has been quite rapid, and departs very far from the value given by the ordinarily accepted formula $\frac{1}{r^2 \Delta^2}$. Comets are so erratic in this respect that no fixed formula of light-increase can be adopted. From a long series of estimates by various observers on Comet 1898 I,[1] the writer found that this comet followed quite closely the purely empirical formula $\frac{1}{r^7 \Delta^2}$; using this ratio, the calculated magnitude of Comet Halley on December 16th would have been about 10.6.

[1] *A. N. Erg. H.*, No. 3.

Photographs taken with the Crossley reflector on December 12th, 13th, and 14th recorded a coma of about 1′ in diameter, with an exposure of thirty-five minutes; an exposure of two hours shows the surrounding halo, though very faintly in the outer portions, with a diameter of about 5′. These plates show also very faint traces of a short tail, following and directed slightly to the north. As the angle at the comet between the radius vector and the line connecting the comet and the earth was less than 2° on this date, this may correspond to a tail of moderate length.

The following ephemeris has been computed by Father SEARLE, assuming perihelion as April 19.69.

	α	δ
1910 January 2	$2^h\ 14^m\ 37^s$	$+11°\ 23'.3$
4	7 50	11 5 .2
6	2 1 21	10 47 .8
8	1 55 11	10 31 .1
10	49 21	10 15 .3
12	43 49	10 0 .4
14	38 35	9 46 .4
16	33 39	9 33 .4
18	29 0	9 21 .3
20	24 38	9 10 .2
22	20 31	9 0 .0
24	16 38	8 50 .6
26	12 59	8 42 .1
28	9 34	8 34 .5
30	6 21	8 27 .6
February 1	3 18	8 21 .5
3	1 0 25	8 16 .2
5	0 57 43	8 11 .5
7	55 10	8 7 .5
9	52 46	8 4 .0
11	50 29	8 1 .0
13	48 19	7 58 .7
15	46 15	7 56 .9
17	44 17	7 55 .5
19	42 24	7 54 .5
21	40 36	7 53 .8
23	38 52	7 53 .5
25	37 11	7 53 .6
27	35 33	7 53 .8
March 1	33 57	7 54 .3
3	32 23	7 54 .9
5	0 30 51	+7 55 .8

According to elements by Dr. SMART, the comet will be closest to the Earth on May 20th, when its distance will be 14,300,000 miles. There is considerable probability that the Earth will pass through the tail on May 18th.

H. D. CURTIS.

GENERAL NOTES.

The Copley Medal of the Royal Society has been awarded to Dr. G. W. Hill for his researches in mathematical astronomy.

"Dr. Hill's work in the branch of astronomy that is farthest removed from popular view, and his exacting application of the higher mathematics to problems requiring the most rigid and complicated demonstration and proof, have done much to facilitate recent progress and to place that progress upon a sure basis."

A Bright Meteor.—On December 12th at 6:40 P. M., Pacific Standard Time, a very brilliant meteor was seen by Miss Nellie Ford and Miss Marjorie Driscoll, students in general astronomy at Stanford University. It appeared about ten degrees west of the Pole Star, moved very slowly westward and disappeared behind the western hills after being visible about half a minute (possibly exaggerated). The meteor was many times brighter than *Venus*, and its trail was visible for the whole length of its path for ten or fifteen seconds after the meteor disappeared. S. D. T.

The library of the late Professor Newcomb has been purchased by Mr. John Claflin for the College of the City of New York.

Under a resolution of the Board of Directors of the Astronomical Society of the Pacific passed July 13, 1907, the by-laws of the Society, together with the statutes governing the bestowal of the Bruce Medal and the rules relating to the Donohoe Comet-Medal, have been reprinted in this number of the Publications. Amendments to the by-laws made since they were last printed in 1897 have been incorporated.

Dr. Karl Schwarzschild, professor of astronomy at Göttingen, has been appointed director of the Astrophysical Observatory at Potsdam.

NEW PUBLICATIONS.

Annales de l'Observatoire Royal de Belgique. Tome XII. Fascicule I.

Les co-ordonnées absolues des étoiles déduites des feuilles héliogravées de la Carte du ciel.

Correction de la position et diamètre de *Mercure* déduits des observations de contact effectuées lors du passage du 15-14 Novembre 1907.

Observations faites au cercle méridien de Repsold en 1908.

Observations solares effectuées á Uccle en 1908.

Bruxelles. 1909. Folio. 307 pp. Paper.

Annuarie pour l'an 1910 publié par le Bureau des Longitudes. Paris. Avec des Notices Scientifique. 24°. 834 pp. paper.

Annuario del Observatorio Astronómico Nacional de Tacubaya parael año de 1910. Mexico. 1909. 16°. 602 pp. Paper.

Astronomische Beobachtungen auf der Königlichen Universitäts-Sternwarte zu Königsberg. Abteilung 42. Rektaszensions-Beobachtungen von 4066 Sternen. Angestellt von FRITZ COHN. Königsberg. 1909. Folio. 355 pp. Paper.

BEMPORAD, A. L'Assorbimento selettivo della radiazione solare nell'atmosfera terrestre. Roma. 1909. 4°. 111 pp. Paper.

BALCELLS, P. MARIANO. L'Observation solaire. Mémoires de l'Observatoire de l'Ebre. No. 2. Barcelone. 1909. 4°. 133 pp. Paper.

ENEBO, SIGURD. Beobachtungen veränderlicher Sterne. Kristiania. 1909. 8°. 60 pp. Paper.

JONES, HARRY C., and ANDERSON, JOHN A. The absorption spectra of solutions. Washington. 1909. 4°. 110 pp., with 81 plates. Cloth.

KOCH, JOHN. Dispersionsmessungen an Gasen im sichtbaren und im ultraroten Spektrum. Upsala. 1909. 4°. 60 pp. Paper.

Meddelanden från Lunds Astronomiska Observatorium. Serie II. Lund 1909. 4°. Paper.

No. 5. Über die Bewegung der Bahnebenen der Satelliten in unserem Planetensystem. C. V. L. CHARLIER. 35 pp.

No. 6. Sur une classe de singularités dans le problème de *n* corps, par HENRIK BLOCK. 57 pp.

Neue Annalen der K. Sternwarte in München. Band IV. Katalog von 1436 Sternen, hauptsächlich Zenitsternen. München. 1909. Folio. 242 pp. Paper.

Perth Observatory. Vol. 3. Meridian Observations 33° to 35° south. Epoch 1900. Perth. 1909. Folio. 59 pp. Cloth.

Publications de l'Observatoire Central Nicolas. Série II. Vol. XVIII, III. Beobachtungen am grossen Zenitteleskop. A. ORLOFF. St. Pétersbourg. 1908. Folio. 66 pp. Paper.

Publikationen der Kaiserlichen Universitäts-Sternwarte zu Jurjew. (Dorpat.)

A. ORLOFF. Graphische Methode zur Auswahl der Sternpaare für die Breitenbestimmung nach der Methode gleicher Zenitdistanzen.

E. SCHOENBERG. Sternbedeckungen durch den Mond beobachtet in den Jahren 1905-09.

Beobachtungen des *Jupiter* am Zenittelescop im März 1908. Dorpat. 1909. Folio. 24 pp. Paper.

Mitteilungen der Grossh. Sternwarte zu Heidelberg. Karlsruhe. 1909. 8°.

XV. Die Bahnen der am 3 August und am 28 September, 1905, erschienenen hellen Meteore. P. MOSCHICK. 32 pp.

XVI. Doppelsternmessungen am zwölfzölligen Refraktor des Astronomisches Instituts. 59 pp.

XVII. Helligkeitsmessungen von lang periodischen Veränderlichen. 97 pp.

The tidal and other problems. T. C. CHAMBERLAIN, F. R. MOULTON, and others. Washington. 1909. 8°. 264 pp. Paper.

Solar eclipse expedition to Flint Island, January 3, 1908. F. K. McKLEAN and others. Suffolk. Folio. 18 pp., with 15 plates. Cloth.

ZINNER, E. Über die sekularen Störungen im planetarischen Rotationsproblem. Lund. 1909. 8°. 25 pp. Paper.

Minutes of the Meeting of the Board of Directors, held in the Students' Observatory, Berkeley, California, November 27, 1909, at 7:30 p. m.

In the absence of President Campbell, the chair was occupied by Professor A. O. Leuschner.

The following were elected to membership in the Society:—

Mr. John S. Hodgin,
Mr. Thomas T. Greaves,
Mr. Charles F. Hart,
Mr. E. D. Rodgers.

Application for life membership in the Society was received from Dr. C. D. Perrine and favorably acted upon.

Minutes of the Meeting of the Astronomical Society of the Pacific, held in the Students' Observatory, Berkeley, California, November 27, 1909, at 8 p. m.

Professor A. O. Leuschner presided over the meeting.

Dr. Heber D. Curtis, of Lick Observatory, delivered a most interesting lecture upon "Astronomical Problems of the Southern Hemisphere and the Work of the D. O. Mills Expedition." The lecture was illustrated by many excellent lantern slides, throwing light upon the scientific subjects discussed, and descriptive also of the Chilean environment in which Dr. Curtis has spent the past two years as director of the expedition.

The exercises of the evening closed with an illustrated lecture by Dr. T. J. J. See, of the Mare Island Naval Observatory, on "The Origin of the So-Called Craters on the Moon." According to the theory of Dr. See, the "craters" are the result of collision between the moon and bodies from outer space. The remarks of the speaker called forth some adverse criticism from members present and resulted in a spirited debate. Adjourned.

D. S. Richardson,
Secretary.

OFFICERS OF THE SOCIETY.

Mr. W. W. CAMPBELL .... *President*
Mr. G. E. HALE .... *First Vice-President*
Mr. F. MORSE .... *Second Vice-President*
Mr. E. J. MOLERA .... *Third Vice-President*
Mr. D. S. RICHARDSON .... *Secretary and Treasurer*
Mr. R. G. AITKEN (Mount Hamilton, Cal.) .... *Secretary*

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CRAWFORD, CROCKER, CUSHING, GALLOWAY, HALE, MOLERA, RICHARDSON.

Finance Committee—Messrs. MOLERA, CROCKER, CUSHING.

Committee on Publication—Messrs. TOWNLEY, MADDRILL, CURTIS.

Library Committee—Messrs. CRAWFORD, TOWNLEY, EINARSSON.

Comet-Medal Committee—Messrs. CAMPBELL (ex-officio), TOWNLEY, CURTIS.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. TOWNLEY, Stanford University, California.

The Secretary will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.

VOLUME XXII.

1910.

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PRINTED FOR THE SOCIETY
1910.

COMET *a* 1910. NEGATIVE BY MERRILL AND OLIVIER OF LICK OBSERVATORY. 1910 JANUARY 27. EXPOSURE $6^h\ 31^m$ TO $6^h\ 31^m\ 5^s$ P. S. T.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XXII. SAN FRANCISCO, CALIFORNIA, FEBRUARY, 1910 No. 130

LIST OF MEMBERS

OF THE

ASTRONOMICAL SOCIETY OF THE PACIFIC.

JANUARY 1, 1910.

OFFICERS OF THE SOCIETY.

Mr. W. W. CAMPBELL .... *President*
Mr. G. E. HALE .... *First Vice-President*
Mr. F. MORSE .... *Second Vice-President*
Mr. E. J. MOLERA .... *Third Vice-President*
Mr. D. S. RICHARDSON .... *Secretary and Treasurer*
Mr. R. G. AITKEN (Mount Hamilton, Cal.) .... *Secretary*

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CRAWFORD, CROCKER, CUSHING, GALLOWAY, HALE, MOLERA, RICHARDSON.

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Comet-Medal Committee—Messrs. CAMPBELL (ex-officio), TOWNLEY, CURTIS.

BRUCE MEDALISTS.

SIMON NEWCOMB† ....
Prof. ARTHUR AUWERS .... Linden Str. 91, S. W. Berlin, Germany.
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FOR REVIEW.

[See *Publications* A. S. P., Vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San Jose, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

FIG. 1. THE MOON EIGHT DAYS OLD—FROM PHOTOGRAPH BY LOEWY AND PUISEUX AT THE PARIS OBSERVATORY.

THE ORIGIN OF THE SO-CALLED CRATERS ON THE MOON BY THE IMPACT OF SATELLITES, AND THE RELATION OF THESE SATELLITE INDENTATIONS TO THE OBLIQUITIES OF THE PLANETS.

By T. J. J. See.

In a paper recently published in the *Astronomische Nachrichten,* No. 4367, November, 1909, the writer has treated of the problem of the obliquities of the planets from the point of view of the capture theory,[1] and has shown that *Jupiter's* small obliquity has been produced by the capture and absorption by that giant planet of vast quantities of satellites moving about the Sun in planes nearly coinciding with the plane of the planet's orbit. It is shown by calculation that if the mass of *Saturn* were increased by this process of capture till it became equal to that of *Jupiter,* the obliquity of *Saturn* would become as small as that of *Jupiter;* whence it is inferred that *Jupiter's* obliquity was once large and afterwards gradually destroyed by the growth of his mass from the capture of satellites moving near the plane of his orbit. This theory of the planetary obliquities is applied to the other planets of the solar system, and the facts are shown to be in good agreement with the theory.

The origin of the lunar craters has long been a debated question in astronomy, but the traditional opinion dating from the time of Galileo is that they are volcanic; and this view is still held by leading investigators, such as M. Puiseux, of the Paris Observatory, and Professor Ebert, of Munich. The theory that the lunar craters are volcanic seems to have originated with Hooke, in 1667, and was generally held till the time of Humboldt. About the middle of the nineteenth century, however, several investigators, but especially Humboldt himself, and Schmidt, of Athens, became doubtful of the

[1] The responsibility for the views here set forth rest with the author, and not with the Society or the Committee on Publication. For the sake of brevity the statements are put as directly as possible, and to some minds seem too categorical. The author believes, however, that brevity has advantages, and that the aim of simple, direct exposition will not imply a spirit of dogmatism.

volcanic origin of these circular mountains, mainly because the inner parts of the craters were found to be depressions, with the central peaks below the average level of the lunar surface. A tentative theory that the craters might be due to impact was outlined by PROCTOR in 1873, mentioned by NEWCOMB as a curiosity in 1878, and more fully worked out by the geologist G. K. GILBERT in 1892; but it has never been accepted either by geologists or astronomers.

After a careful examination of all the evidence, I am satisfied that the impact theory is correct, and that the current volcanic theory is not well founded. It happens that the impact theory brings the phenomena of the lunar surface into harmony with the capture theory of satellites and of the obliquities of the planet; and it will therefore contribute to our understanding of the phenomena of the solar system. If *Jupiter's* small obliquity has been produced by the capture and absorption of satellites, the evidence of such collisions, preserved by the indentations in the Moon's face, becomes an important chain in the reasoning for establishing the processes involved in the formation of the solar system. The present discussion is restricted to a brief summary, but the reader who is interested in the subject should be referred to a paper recently communicated by the writer to the *Astronomische Nachrichten,* and to GILBERT'S important paper of 1892,[1] all of which will be treated more fully in the forthcoming Volume II of my "Researches on the Evolution of the Stellar Systems."

It is found that the impact theory explains the following facts:—

(1) Both large and small craters, and their superposition over one another, some being older and others newer, as the case may be.

(2) The frequent occurrence of small craters on the rims of large ones, where they would scarcely arise from eruptive causes.

(3) The existence of craters in perfectly smooth plains, as well as in rough and broken regions; and the unequal density of the craters in different parts of the lunar surface. Terrestrial volcanoes generally follow the mountain ranges along the sea coasts. On the Moon the craters are scattered indis-

[1] *Bulletin of the Philosophical Society of Washington,* Vol. XII.

criminately, except that they are rare in the maria, for reasons which will hereafter appear.

(4) The greater steepness of the inner walls, and the great diameters of the larger craters, which could not well be explained by volcanic forces. If it be thought that more large craters ought to be elliptical than are observed, it may be recalled that even if the first contact with the Moon produced such an outline, the impact of a large satellite would generate enough heat and underlying flow to force out the walls about symmetrically all around, and the final figure would be circular like the globular figure of the satellite. Thus craters which are, say, ten times as wide as they are deep, ought to be almost circular; while smaller craters would be more irregular and elliptical, as found by observation. This is because the forcing out of the material beneath small craters is less effective than in the case of large craters, and they retain more nearly their original shape of first contact.

(5) The very flat-bottomed craters, noticed in such regions as Mare Nubium, are due to the filling up of deeper and more irregular craters with cosmical dust, or by melted material which has assumed a level surface. This has at length become so deep as to leave only the walls visible about a level central area, while the central peaks have been nearly or entirely covered up.

(6) In many cases the lunar photographs show that even the walls are practically covered up; for they can now be traced with difficulty, and merely as a faint outline. The walls are covered up, especially in the so-called maria. So far as one can see, two, and only two, explanations of these so-called ghost craters are possible: (1) The deposit of cosmical dust from the heavens and from the conflagrations arising in the impact of satellites; (2) The partial melting down of the walls by the conflagrations, which produced the maria, so that only an outline of the original crater walls can be traced. The fact that the ghost craters occur chiefly in the level maria supports the conflagration and melting hypothesis, and this certainly is one of the leading causes. But since the earlier craters away from the maria also show the effects of age, as if tending to become obliterated by falling dust, this latter cause also is at work. Moreover, the two causes necessarily are related.

Together they explain the ageing of the craters in the rough regions far from the maria, as well as the buried or ghost craters in the maria themselves.

(7) This shows that many craters have not only been obscured and partly blotted out by the falling dust, but also that a countless number of these objects have been permanently buried by the process of deposit and conflagration. The so-called seas are areas once made level by melting, in which few recent craters have been found. The seas of the Moon appear to be singularly level, and this can only point to terrible impacts at some time in the past by which these whole areas were so fused that pretty much all inequalities of level disappeared. They have since been covered with a layer of cosmic dust, but have suffered relatively few large indentations. They generally appear dark because the surface is nearly level, and the Sun's light when reflected is but little scattered and seldom so directed that the beam from any considerable part of the surface passes near the eye of the observer.

(8) If this view be correct, it also indicates that the whole Moon was formed by accretion, and that the surface never did experience true eruptive phenomena, such as we observe on the earth.

(9) The interior of the lunar craters is generally below the level of the surrounding normal surface, and this cannot well be explained except by impact. Volcanic eruptions could not well produce depressions of the crater basins. "The bottoms of many of the craters are very deeply depressed below the general surface of the Moon, the internal depth being often twice or three times the external height."[1] This remark of Sir John Herschel shows that decided depressions of the basins is common to all craters, both those with rims and those without. It is almost impossible for volcanic forces to produce such a result. One or two Hawaiian volcanoes are the only depressed craters on the earth, and they are recognized to be exceptions to the general rule of elevation characteristic of our planet.

(10) It is evident that the craters have not been produced by the removal of material from the center and the piling of it up to make the surrounding walls: for in probably three

[1] Herschel, "Outlines of Astronomy," § 430.

fourths of the cases, as Professor H. EBERT has shown, it is easily proved by calculation that the volume of the excavation exceeds the volume of the material contained in the wall. This remarkable volume relationship would be explained if the matter beneath the crater were compressed by the force of impact, and only a part of it and of the falling satellite forced out to form the surrounding walls.

(11) The shorter streaks radiating from such craters as Copernicus and Aristarchus are easily explained. It is sufficient to suppose that the collision was so forceful that matter was scattered far out in all directions, and perhaps heated to fusion in the process; yet as the Moon has no oxygen, it did not burn and blacken as meteoric stones do in falling on the Earth, but simply took on a fused and glassy aspect, which, by reflection, gives the brightness of the shorter streaks radiating from Tycho and its associates. This explanation was given by Mr. WÜRDEMANN, of Washington, D. C., many years ago, in a letter to Dr. B. A. GOULD, but it seems to be but little known to astronomers.

(12) The long rays from craters such as Tycho are similar optical effects of glassy material falling on walls of craters lying nearly in a straight line, and radiating from this center. This is shown by the photographs. Any crater which had matter ejected from it radially, in the process of formation, will have a system of rays, due to the effect of the sunlight on the higher elements of the surface traversed by the rays running from the crater as a center.

(13) As the Moon's force of gravity is feeble, the vapor and metallic and the lithic rain due to impact might be carried hundreds of miles, and these streaks due to material falling on corrugations and ridges might extend out from the craters for a considerable distance, and sometimes appear to be prolonged by coincidence with other crater walls or ridges.

(14) The considerable number of craters which are simple depressions without sensible walls are to be explained by the comparative looseness of the material of the Moon's surface layers,—which allows the mass to yield downward without throwing up much of a wall about the depression produced.

(15) The clefts are paths cut by glancing satellites, which thus leave a straight or curved line, according to the nature

of the surface and the resistance and rebound. Photographs confirm this origin of the clefts, and show that they are not cracks but actual cuts, sometimes more than a hundred miles in length.

(16) Rills are cracks or offsets along walls of craters which often are more or less hidden by later deposits. They pursue in some cases an irregular course, and often may be due to settlement of the loose material, as in landslides on the Earth.

(17) Changes in the aspects of a crater due to caving in, settlement, etc., are always possible; but to be entirely certain that the change is real, the illumination has to be exactly the same at the two epochs, which is seldom possible. If the suspected changes are real, photography will eventually establish this fact.

(18) The covering up of ancient cities on the Earth is due to deposits of waste, rubbish, and dust traceable to meteorological causes connected with the atmosphere, such as sand borne by the wind from the deserts, etc. On the Moon, however, there is no atmosphere sufficiently dense to carry dust, and it must therefore be scattered by impacts and by direct descent from celestial space. The fact that the older craters are visibly covered up is a tangible proof of the great part played by cosmical dust in the course of ages.

(19) The different degrees of obliteration shown by the various lunar craters is an impressive witness to the progressive falling of cosmical dust in a celestial world devoid of rain or other meteorological disturbance of any kind.

(20) At zero degrees centigrade the maximum molecular velocities of the atmospheric gases are found by Dr. JOHNSTONE STONEY to be as follows: Oxygen, 1.8 miles per second; nitrogen, 2.0; water vapor, 2.5; helium, 5.2; hydrogen, 7.4. These values usually decrease with the fall of temperature, but the modification thus arising is not very considerable for small changes.

(21) Now, at the surface of the Moon, the parabolic velocity is 1.5 miles per second (2.37 kilometers),[1] and therefore none of these atmospheric gases can be retained. For, although we do not know the Moon's temperature very accurately, it would seem that during the lunar night, it must approach the

[1] *Astronomische Nachrichten*, 3992, p. 136.

FIG. 2. IMPRINTS OF RAINDROPS, FROM CHAMBERLIN AND SALISBURY'S GEOLOGY.

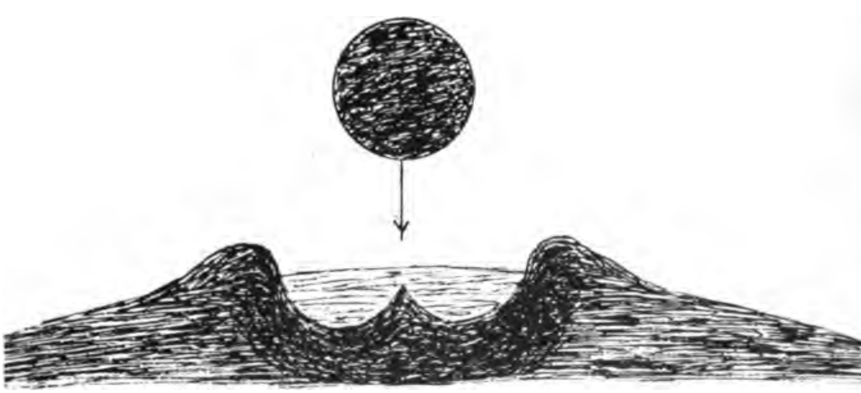

FIG. 3. ILLUSTRATION OF FORMATION OF CRATER BY IMPACT OF SATELLITE.

absolute zero, while during the day it cannot well exceed the boiling-point of water. Accordingly the above values are not sensibly altered by the admissible variations of temperature.

(22) Observations on the refractions of stars occulted by the Moon prove that if any sensible atmosphere exists at the lunar surface, it does not exceed 1/5000 part of the density of the terrestrial atmosphere. We may therefore conclude that no sensible atmosphere has ever existed upon the Moon, either before or since the capture by the Earth; but that the vapors there arising have congealed into dust or constantly escaped into space.

(23) The cosmical dust that falls upon the Moon therefore encounters no atmospheric resistance, but plunges headlong against the lunar surface. Any vapor due to the force of collision quickly cools and is, if it condenses into solid particles, precipitated as dust, and nowhere amounts to a permanent cloud. If it remains true gas, the molecules gradually escape into space, or are absorbed into the rock of the surface.

(24) If now we compare the lunar photographs with the accompanying imprints made by raindrops, and by bullets fired into a leaden disc as a target, we shall notice the most remarkable similarity in the two effects. The raindrops, however, are all fluid, and leave only saucer-shaped imprints, and no central peaks; whereas the leaden bullets and stony satellites indenting the lunar surface would necessarily leave central peaks, in accordance with observations. Thus the Moon's surface can be nothing but fragments of rock filled with finer dust; and it is evident that it has never been molten as a whole and has never shown true volcanic activity, as known upon the Earth.

The last conclusion is confirmed from another point of view by an exact calculation given in *Astronomische Nachrichten,* 4053, page 345, showing that the total gravitational heat of condensation of the matter of the Moon would raise an equal mass of water through only 408 degrees centigrade. It is there pointed out (page 348) that the development of such a small amount of heat, in the course of long ages, would not at any time give rise to a temperature that would produce fusion of rock. Even when radio-active substances are considered, the conclusion is the same,—namely, that in the slow and almost insensible development of the Moon

by accretion, enough heat to produce general fusion could not have arisen.

Accordingly, we may dismiss the old volcanic theory once for all as false and misleading; and may look upon our satellite as a battered planet, which presents to us the most lasting and convincing evidence of the processes of capture and accretion by which the heavenly bodies were formed.

The strength of the present argument regarding the origin of the lunar craters does not rest on one class of phenomena alone, but on several distinct classes of phenomena, which are all harmonized among themselves and brought into accord with the necessary processes of planetary growth. Since worlds form in nebulæ, it follows that impacts will necessarily occur; and the Moon's face shows the size of these masses by their imprints, which thus throw an unexpected light upon the state of the solar system in the remote past.

The variability of the satellites of *Jupiter* and *Saturn*, photometrically investigated by GUTHNICK, in *Astronomische Nachrichten*, 4023 and 4098, indicates that they, too, have maria covering their surfaces, due to collisions, as in the case of the Moon. For, as observed from a distance, the Moon also would be variable, according to the extent of the maria on the side toward the Sun. Lastly, the mathematical argument regarding the capture of the satellites and the Moon is confirmed by SCHROETER's observations, 1789-1793, showing that the planet *Venus* rotates in 23 hours 21 minutes. For if *Venus* has that period, the Earth never could have rotated faster than at present, and the Moon necessarily would be a captured planet. There is found also to be a theoretical reason why *Venus* ought to rotate faster than the Earth, so that the capture of the Moon is confirmed both by the observations of *Venus* and by mathematical theory, and the origin of the lunar craters by impacts is a necessary corollary to the capture theory of satellites.

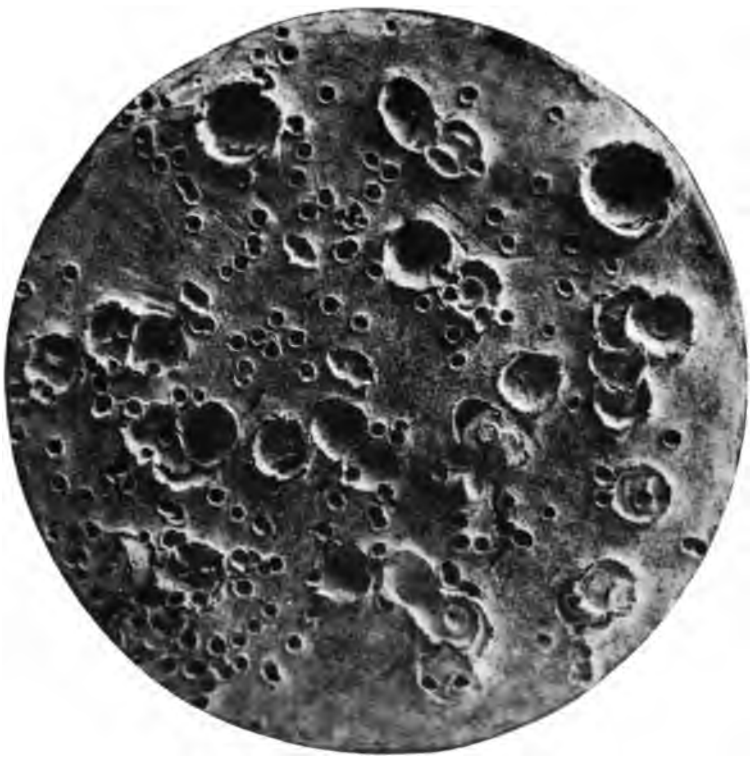

FIG. 4. INDENTATION OF LEADEN TARGET BY BULLETS, FROM EXPERIMENTS MADE BY CAPT. A. W. DODD, U. S. N., AT MARE ISLAND.

ASTRONOMICAL OBSERVATIONS IN 1909.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris.*[1]

Jan.	8:	S = g.
	24:	id.
	25:	id.
Feb.	6:	id.
	12:	> g. < f.
	13:	= f.
	16:	id.
	19:	id.
	20:	in the midst. between e and f.
	21:	id.
Mar.	1:	< e. > f.
	18:	= e.
Apr.	1:	= d.
	15:	3 steps > d.
	19:	id.
	21:	5 steps > d.
	26:	id.
May	6:	6 steps > d.
	10:	4 steps > d.
	20:	id.
Aug.	6:	= g.
	8:	1 step > g.
	14:	id.
Aug.	16:	= g.
	23:	id.
Sept.	5:	id.
	8:	id.
	11:	id.
	15:	> g. < f.
	16:	id.
	21:	3 steps > g.
Oct.	1:	in the midst. between e and f^1.
	6:	2 steps < e.
	9:	id.
	10:	1 step < e.
	27:	3 steps > d.
Nov.	10:	2 steps > d.
	11:	2½ steps > d.
	15:	2 steps > d.
	17:	id.
	20:	id.
	24:	1 step > d.
Dec.	15:	id.
	21:	4 steps > d.
	27:	id.
	30:	3 steps > d.

T *Ursæ Majoris.*[2]

Jan.	8:	T invisible.
	24:	id.
	25:	id.
Feb.	6:	id.
	12:	id.
	13:	id.
	16:	id.
Feb.	19:	id.
	20:	id.
	21:	id.
Mar.	1:	id.
	18:	id.
Apr.	1:	id.
	15:	< g.

[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.
[2] Vide the sketch in the *Publications A. S. P.*, No. 22, **4**, 63.

Apr.	19:	id.
	21:	$\begin{cases} > \text{f.} \\ < \text{e.} \end{cases}$
	26:	2 steps < d.
May	6:	= c.
	10:	1 step > c.
	20:	id.
Aug.	6:	1 step > f.
	8:	= f.
	14:	1 step < g.
	16:	1 step < f.
	23:	2 steps < f.
Sept.	5:	faint.
	8:	very faint.
	11:	id.
	15:	id.
Sept.	16:	id.
	21:	invisible.
Oct.	1:	id.
	6:	id.
	9:	id.
Nov.	10:	id.
	15:	id.
	17:	id.
	20:	id.
	24:	id.
Dec.	7.	id.
	15:	id.
	21:	id.
	27:	1 step > e.
	30:	1 step < d.

W *Pegasi*.[1]

Jan.	8:	W = c.
Feb.	12:	$\begin{cases} < \text{e.} \\ > \text{f.} \end{cases}$
	13:	id.
	16:	id.
	19:	= f.
	21:	id.
May	20:	invisible.
	21:	id.
Aug.	8:	= f.
	14:	id.
	16:	1 step < f.
	19:	$\begin{cases} < \text{f.} \\ > \text{g.} \end{cases}$
	23:	id.
	28:	id.
Sept.	5:	id.
	8:	$\begin{cases} > \text{f.} \\ < \text{e.} \end{cases}$
	11:	id.
	14:	= e.
Sept.	16:	$\begin{cases} < \text{e.} \\ > \text{f.} \end{cases}$
	21:	= e.
Oct.	1:	$\begin{cases} \text{in the midst} \\ \text{between c and d.} \end{cases}$
	6:	= c.
	9:	1 step > c.
	10:	3 steps > c.
Nov.	10:	1 step > b.
	11:	1 step < b.
	15:	id.
	16:	id.
	17:	id.
	18:	id.
	20:	id.
	24:	3 steps < b.
Dec.	7:	= c.
	21:	= d.
	27:	1 step < d.
	30:	id.

SS *Cygni*.[2]

Jan.	8, 6^h:	SS $\begin{cases} > \text{e.} \\ < \text{f.} \end{cases}$
	23, 19^h:	invisible.
Feb.	21, 7^h:	= f.
Apr.	19, 10^h:	= d.
	26, 10^h:	1 step > c.
May	6, 11^h:	$\begin{cases} < \text{e.} \\ > \text{f.} \end{cases}$

[1] Vide the sketch in the *Publications A. S. P.*, No. 60, **10**, 23.
[2] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 18.

May	20, 12^h:	= f.
Aug.	6, 10^h:	1 step < c.
	7, 10^h:	id.
	8, 10^h:	id.
	9, 10^h:	1 step > d.
	10, 10^h:	1 step < d.
	14, 10^h:	= e.
	16, 10:	id.
	23, 12^h:	2 steps < f.
	28, 9^h:	1 step < f.
Sept.	5, 9^h:	= f.
	8, 9^h:	$\left\{ \begin{array}{l} < \text{f.} \\ > \text{g.} \end{array} \right.$
	11, 12^h:	id.
Sept.	14, 8^h:	= g.
	16, 8^h:	= f.
Oct.	6, 10^h:	1 step < f.
	9, 9^h:	= f.
Nov.	10, 9^h:	= g.
	15, 10^h:	id.
	17, 8^h:	$\left\{ \begin{array}{l} < \text{f.} \\ > \text{g.} \end{array} \right.$
	18, 8^h:	= f.
Dec.	15, 10^h:	2 steps > d.
	16, 9^h:	2 steps < d.
	21, 6^h:	$\left\{ \begin{array}{l} > \text{f.} \\ < \text{e.} \end{array} \right.$
	27, 6^h:	= g.

Z *Cygni*.[1]

Jan.	8:	Z invisible.
	24:	id.
Feb.	21:	id.
Apr.	19:	id.
	26:	id.
May	6:	id.
	10:	$\left\{ \begin{array}{l} > \text{e.} \\ < \text{d.} \end{array} \right.$
	21:	$\left\{ \begin{array}{l} > \text{d.} \\ < \text{c.} \end{array} \right.$
June	16:	$\left\{ \begin{array}{l} \text{2 steps} < \text{a.} \\ \text{4 steps} > \text{b.} \end{array} \right.$
Aug.	8:	1 step > c.
Aug.	14:	$\left\{ \begin{array}{l} < \text{c.} \\ > \text{d.} \end{array} \right.$
	16:	id.
Sept.	11:	2 steps < e.
Oct.	6:	< e.
Nov.	11:	5 steps < e.
	15:	invisible.
	18:	id.
Dec.	15:	id.
	21:	id.
	27:	id.
	30:	id.

U *Herculis*.

Jan.	24:	$\left\{ \begin{array}{l} < \text{g.} \\ > \text{h.} \end{array} \right.$
Apr.	26:	invisible.
May	7:	id.
	10:	id.
	21:	id.
Aug.	6:	id.
	14:	1 step < h.
	16:	$\left\{ \begin{array}{l} \text{1 step} > \text{h.} \\ \text{2 steps} < \text{g.} \end{array} \right.$
	23:	a little > g.
	28:	$\left\{ \begin{array}{l} \text{in the midst.} \\ \text{between f and g.} \end{array} \right.$
Sept.	5:	1 step < e.
	8:	= e.
Sept.	11:	1 step > e.
	14:	= d.
	15:	id.
	16:	$\left\{ \begin{array}{l} > \text{d.} \\ < \text{c.} \end{array} \right.$
	21:	2 steps < c.
Oct.	1:	$\left\{ \begin{array}{l} \text{in the midst.} \\ \text{between c and d.} \end{array} \right.$
	6:	$\left\{ \begin{array}{l} > \text{d.} \\ < \text{c.} \end{array} \right.$
	9:	½ step > d.
Nov.	10:	1 step > f.
	16:	= f.
	18:	3 steps < f.
	24:	2 steps < f.

[1] Vide the sketch in the *Publications A. S. P.*, No. 100, 17, 16.

I have used the sketch in the *Publications A. S. P.*, No. 106, **18**, 52, but have added the two small neighboring stars g at a and h at f, both northward.

Y *Tauri* (B. D. + 20° 1083).

A number of twenty comparisons have been made upon this irregular variable star. While in the year 1908 Y was noted either equal to or brighter than the star A = B. D. + 20° 1095 ($7^m.4$), it was in the year 1909 after February 12th fainter than A.

TV *Cygni.*

This star (B. D. + 46° 2970), mentioned in the *Publications A. S. P.*, No. 77, **13**, 18, has in the past year undergone some slight variations, but any period has yet not been detected.

METEORS.

Fireballs have been observed from stations in Denmark at the following dates: January 8th, 10th, 13th, 20th; February 8th, 9th, 16th; April 5th, May 19th, June 10th, August 10th, 19th; September 14th, 20th, 27th; October 9th, 23d; November 8th, 10th, 14th, 17th, 21st; December 5th. My Meteor Catalog shows large fireballs on September 27th-28th in the years: 1870, 1876, 1877, 1880, 1887, 1890, 1892, 1893, 1900, and 1909. December 12th-13th is also designated as a meteor-day.

SHOOTING-STARS.

Shooting-stars were observed from nine stations in Denmark on August 9th, 10th, 11th, 12th, 19th, and September 14th. At these stations 217 paths of shooting-stars were mapped, but only ten proved suitable for calculation. These ten meteors have given the following results:—

From Observation.

No.	Time.	Station.	Beginning.	Ending.	Mag.	Observer.
1	Aug. 9, 11^h 3^m 0^s P.M.	Odder	35° + 78°	220° + 79°	1	T. Köhl.
		Copenhagen	196 + 56	203 + 40.5	♃	O. Asmussen.
2	Aug. 10, 9 35 0	Fredericia	42 + 54	33 + 50	> ♀	Ch. Frost.
		Aarhus	21 + 61	0 + 53	1	H. Aae.
3	Aug. 10, 10 16 10	Kolding	....	355 + 9	1	H. Nielsen.
		Odder	....	345 + 4	1	T. Köhl.
4	Aug. 10, 10 23 50	Odder	354 + 21	348 + 10	3	T. Köhl.
		Copenhagen	320 + 50	297 + 32	1	O. Asmussen.
		Sönderborg	....	18 + 28	2	Maria Wolff.
		Vallekilde	....	336 + 23	1	K. Kaestel.
5	Aug. 10, 10 47 40	Sönderborg	23 + 37.5	20 + 30	3	Maria Wolff.
		Odder	350 + 20	346 + 9	4	T. Köhl.
6	Aug. 10, 11 20 30	Sönderborg	....	65 + 43.5	2	Maria Wolff.
		Odder	....	27 + 36.5	1	T. Köhl.
7	Aug. 10, 11 23 30	Odder	355 + 11	350 ÷ 1	2	T. Köhl.
		Vallekilde	246 + 34	241 + 14	1	K. Kaestel.
8	Aug. 10, 11 36 0	Sönderborg	45 + 45.5	54 + 39	1	Maria Wolff.
		Odder	25 + 40	20 + 27	♃	T. Köhl.
9	Aug. 19, 9 25 48	Odder	320 + 25	329 ÷ 5	½ ☾	T. Köhl.
		Copenhagen	251 + 37	220 + 5	♀	S. A. Kierulff
0	Sep. 14, 8 58 0	Odder	330 + 0	350 ÷ 10	3	T. Köhl.
		Copenhagen	295 + 5	315 ÷ 10	1	K. Ochsner.

From Calculation.

No.	Beginning.			Ending.			Real Length of the Path.	Radiant.	
	h	λ	φ	h	λ	φ	β	AR	Decl.
1	132.8	1° 52′.4 w	56° 48′.4	114.8	2° 50′.5 w	56° 36′.6	67.0	37°	+ 24°
2	106.0	1 9.7 w	56 56.4	77.5	1 19.4 w	56 30.2	57.3	77	+ 61
3				126.1	1 44.7 e	54 43.3			
4A	125.0	0 37.4 e	55 39.0	86.1	0 7.6 e	55 21.8	59.2	32	+ 57
B				86.1	0 7.6 e	55 22.0			
C				87.6	0 8.4 e	55 21.6			
5	112.9	0 11.3 w	55 30.1	86.1	0 21.1 w	55 16.0	39.1	63	+ 71
6				79.0	0 36.7 w	56 16.0			
7	31.5	1 39.8 w	55 43.7	21.2	1 46.9 w	55 39.7	15.7	36	+ 61
8	226.1	1 42.4 e	56 34.3	92.2	0 7.0 w	55 59.2	190.0	32	+ 52
9	124.9	1 5.6 w	55 26.4	28.4	1 25.4 w	55 26.8	97.0	54	+ 53
0	137.9	0 35.0 w	54 13.4	63.6	0 23.2 e	54 28.0	102.0	261	+ 26

h and *β* are expressed in kilometers; λ is longitude from Copenhagen; *φ* is north atitude; *h* is the altitude of the meteor above the Earth's surface. The combination f Odder-Copenhagen is marked A, Sönderborg-Odder B, and Odder-Vallekilde C.

The Carina Observatory at Odder was opened for visitors on every fine evening from 9 to 10 o'clock during August and September. In July the telescope was supplied with a very good clockwork from the mechanician, J. OLSEN, Copenhagen. The estimations of variable stars have often been controlled by my assistants, Mr. J. SKAKKE and Mr. C. MIKKELSEN.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1910.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter.	March 3, $11^h\ 52^m$ P.M.	Last Quarter.	April 2, $4^h\ 48^m$ P.M.
New Moon ..	" 11, 4 12 A.M.	New Moon ...	" 9, 1 25 P.M.
First Quarter.	" 17, 7 37 P.M.	First Quarter.	" 16, 6 4 A.M.
Full Moon ...	" 25, 12 21 P.M.	Full Moon ...	" 24, 5 23 A.M.

The Sun crosses the equator from south to north and spring begins March 21st, 4 A. M., Pacific time.

Mercury is a morning star on March 1st. It passed greatest west elongation on February 19th and aphelion on February 27th. On March 1st it rises a little more than an hour before sunrise and may be seen in the morning twilight if weather conditions are fine. This condition of affairs will last only a few days, however, as the apparent distance between planet and Sun is diminishing; and on April 5th the planet reaches superior conjunction with the Sun, becoming an evening star. By the middle of April the apparent distance will have increased to such an extent that the planet will remain above the horizon for an hour after sunset, and at the end of the month the interval will be only a few minutes less than two hours. This is much larger than it usually is at greatest elongation, being mainly due to the fact that the planet is 8° north of the Sun at the end of April. The angular distance between Sun and planet is not as great as it frequently is at time of greatest elongation. For instance, the greatest west elongation on February 19th was 26° 33′, and the present greatest east elongation, which will occur on May 2d, is only

20° 55′. From the middle of April until the middle of May *Mercury* may be seen in the evening twilight near the western horizon.

Venus is also a morning star, having passed inferior conjunction with the Sun before the middle of February. On March 1st it rises a little more than an hour and one half before sunrise. The interval increases to about two hours by April 1st, and then remains nearly constant for several months. The apparent distance of the planet from the Sun goes on increasing until April 23d, when the planet reaches its greatest west elongation, and then begins to diminish, but the shifting positions of planet and Sun along the ecliptic will counterbalance the effect of diminishing distance, so that *Venus* will continue to rise about two hours before sunrise until after the beginning of September. *Venus* will be at its greatest brightness about the middle of March and can then be seen in broad daylight if the air is clear. This condition may last for some weeks.

Mars, although continually growing fainter, remains in good position for observation in the southwestern and western evening sky. It sets just before midnight on March 1st and about an hour earlier at the end of April. During the two months' period it moves about 40° eastward and 5° northward from the western edge of *Taurus* to the extreme eastern edge of that constellation, or the western part of *Gemini.* On March 10th it is about 3° south of the *Pleiades,* on March 29th it is about 7° north of the first magnitude star *α Tauri, Aldebaran,* and at the end of April it is about half way between this star and *Castor* and *Pollux,* the brightest stars of *Gemini.* Its actual distance from the earth increases from 145 to 195 millions of miles and its brightness diminishes about 50 per cent during the period. At the end of April it is only about one thirtieth of its brightness at the opposition of 1909, and when it reaches its maximum distance from the Earth in September, 1910, its brightness will be only one fiftieth of its opposition brightness. However, even at its minimum it will be easily seen, as it does not become much fainter than the pole star. There will be no difficulty in recognizing it.

Jupiter is in fine position for observation, rising at about half after eight on March 1st, at about sunset on April 1st, and more than two hours earlier on April 30th. It comes to

opposition with the Sun on the evening of March 30th, and is then above the horizon throughout the entire night. Its motion is retrograde in the constellation *Virgo* and amounts to 8° westward and 3° northward, away from *Spica*, the brightest star in the constellation.

Saturn is still to be seen in the southwestern sky in the early evening during March, but is rapidly drawing nearer the Sun. On March 1st it sets about 9 P. M., on April 1st only a little more than an hour after sunset, and it will not then be an easy naked-eye object. It comes to conjunction with the Sun on the evening of April 16th and becomes a morning star.

Uranus is an early morning object in the constellation *Sagittarius*, and is not favorably situated for observation.

Neptune is in the constellation *Gemini*, and is in good position for observation, but is too faint for naked-eye visibility.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on Comet *a* 1910.

On Monday afternoon, January 17th, at 3 P. M., the following telegram was received from the Harvard College Observatory:—

> Kiel cables DRAKE[1] comet five or ten degrees S. S. W. Sun and approaching Sun, Johannesburg January 17th at and after sunrise. WORSSELL JONES seen two mornings ago in Orange Free State.
>
> (Signed) E. C. PICKERING.

While this dispatch is not as clear as it might be, it evidently announced the discovery of an unusually bright comet which would set shortly before the Sun. This object was looked for on Monday afternoon with the aid of smoked glass to cut off the Sun's rays, but was not seen. Monday evening, about 8:30 P. M., another telegram was received, giving an accurate position of the comet by INNES at Johannesburg. From this it appeared that it had passed the Sun and was moving rapidly eastward and northward.

About 11 o'clock on Tuesday, January 18th, it was easily detected here with the unaided eye about 4° east of the Sun and 1° north of it. Close as it then was to the Sun, it was considerably more conspicuous than *Venus*, which was then more than 30° from the Sun.

The sky was hazy and clouds of varying density hid the comet from time to time. On this account the attempts made to observe its transit with the meridian circle and 4-inch transit instrument failed, thick clouds concealing it as it crossed the meridian.

With a very efficient spectrograph attached to the 12-inch telescope Mr. WRIGHT secured excellent visual observations at intervals from 11 A. M. till after 3 P. M. These showed the

[1] Later advices state that this word should have been *great*. A period should probably be inserted after "Jones."

spectrum of the nucleus to be continuous, crossed by the bright D lines of sodium vapor, extending out into the coma. The sunlight falling on the object-glass of the 36-inch telescope prevented satisfactory visual observations with that instrument, but with the 6-inch finder several good views of the head of the comet were obtained in the course of the afternoon. The nucleus appeared very small and very bright, with a sharply defined limb or edge, with no gradual shading off into the coma, resembling a very small planetary image as seen under good observing conditions, except that it was much brighter. Surrounding the nucleus and streaming backward, away from the Sun, were nebulous envelopes, which took the general form of an open umbrella, and could be traced about ½°. Clouds constantly interfered, and finally cut off all view of the comet, so that the arrangements made to secure photographic and spectrographic observations after sunset were fruitless.

On Wednesday, January 19th, efforts made to see the comet by daylight failed and clouds again prevented observations after sunset. Stormy weather followed, and the comet was not seen again until the evening of January 26th, when the sky cleared suddenly shortly after sunset. On the following nights observations were made under as good conditions as could be expected at so great a zenith distance, and spectrographic, polariscopic, and photographic results of value were secured. Visually, without a telescope, the tail could be traced from 15° to 30° on the evenings of January 26th to January 30th. It was best seen by the writer on the evening of January 27th, when it took the form of a long feathery plume, curving slightly toward the south from a vertical direction, until it reached a point about 15° from the head; then the tail forked, and the curvature toward the south of the main part became, rather abruptly, very much more pronounced. This branch could be traced at least 15° further, until it was lost in the zodiacal light, which, unfortunately, was quite bright. The northern fork could only be traced 2° or 3°. The whole northern edge of the tail, including this fork, was distinctly outlined, and could be represented by a smooth curve, but the southern edge had no well-defined boundary after about the first ten degrees.

It is too soon to say what gain to our knowledge of cometary structure will result from this unexpected visitor. The observations made here up to the present time indicate that we shall learn far more from the spectrograms than from the direct photographs, for the comet seems to be of the quiescent type and has not yet shown any of the rapid and abrupt changes in form that made Comet Morehouse so interesting. The spectrograms obtained have as yet received only a preliminary examination, so that definite statements of results cannot be made, but in a general way it may be said that while the comet was very close to the Sun the sodium D lines were very bright, fading out as its distance from the Sun increased, while the hydro-carbon bands became relatively more intense. In these respects the comet's behavior resembled that of the great comet of 1882.

An orbit was computed by Dr. KOBOLD, of Kiel, Germany, from observations on the 17th, 18th, and 19th of January, but it does not represent the comet's subsequent motion satisfactorily.[1]

That the comet has excited unusual attention is evident not only from the many press items relating to it, but also from the number of letters about it that have been received at this observatory. This is natural enough, for it is the only brilliant one that has been seen in our skies since 1882, and public interest in these bodies has been aroused by the return of Halley's Comet, with which the new one has been confused by many.

It may be added that no better opportunity for preliminary training for the observations to be made on Halley's Comet in the spring could be desired than has been afforded by this comet.

R. G. AITKEN.

February 3, 1910.

COMET *a* 1910.

A series of twenty plates has been taken on Comet *a* 1910 with the Crocker photographic doublet by PAUL W. MERRILL and CHAS. P. OLIVIER. The lenses both have an aperture of six inches and focal lengths of 30.8 inches and 32.6 inches,

[1] This is also true of two orbits received later.

respectively. The following table gives the main points of interest found in a preliminary examination of the plates:—

Plate.	Date. 1910.	Exposure.	Nucleus.	Tail. Length.	Tail. Remarks.
1	Jan. 26	3^m	Sharp	4°	Trifurcated
2	26	5	Not very sharp	4	Trifurcated
3	26	3	Fair	6+	Trifurcated
4	26	10	Not on plate	14	Great fork $13^\circ \pm$ from nucleus
β 7	27	11	Elongated N. & S.	8	Trifurcated
δ 8	27	7	Elongated N. & S.	3	
ε 9	27	5	Elongated N. & S.	9+	
ζ 10	27	21	Not on plate	14+	Great fork shows plainly
α 11	28	5½	Strong, round	5	Southern branch relatively stronger
γ 13	29	6	Fair, round	3	
δ 15	29	10	Not on plate	11	Shows general curves well
α 16	29	40	Not on plate	14	Great fork shows plainly
α 17	30	17	Slightly elongated	2	Faint
γ 18	30	9	Good	2+	Faint
δ 20	30	34	Not on plate	Tail barely visible; sky not very clear	

NOTE.—All the above plates were Lumière Σ except 1, β 7, and α 17, which were Seed 27.

All the exposures on the comet proper had to be made between early twilight and $6^h\ 35^m \pm$ P. S. T., because the comet then set behind the main buildings as seen from the Crocker dome. This was most unfortunate, for we were obliged to lose at least fifteen minutes of the best time for exposure. However, in spite of twilight and short exposures, the plates show quite an amount of detail, and a careful study of them will give a good idea of the changes which took place during the interval covered. Those mentioned above in which the nucleus was not on the plate were obtained by guiding on some star in or near the tail. These plates show the general outlines well. Narrow, sharp streamers and bright knots or condensations nowhere appear.

PAUL W. MERRILL,
MOUNT HAMILTON, CAL. CHAS. P. OLIVIER.

HALLEY'S COMET. NEGATIVE BY H. D. CURTIS WITH THE CROSSLEY REFLECTOR. FEBRUARY 5, 1910. EXPOSURE $1^h\,30^m$.

Comet *a* 1910.

Photographs of the head and inner portions of the tail of Comet *a* 1910 were made with the Crossley reflector on February 1st, 2d, and 5th. Of these, that of February 1st is much the strongest. The head proper is very bright, round, without apparent nucleus, and slightly over one minute of arc in diameter. Numerous streamers radiate from this head, but no knots or condensations are shown. The plate of February 5th shows evidences of a nucleus of stellar character. The resulting positions on the three dates are:—

Mt. H. M. T.		Exp.	Apparent. α	Apparent. δ
Feb. 1,	$6^h\,39^m\,25^s$	13^m	$21^h\,38^m\,51^s.01$	$+3°\,19'\,29''.0$
2,	6 33 25	29	21 40 58 .54	+3 56 57 .8
5,	6 38 25	23	21 46 40 .73	+5 34 54 .1

H. D. Curtis.

Halley's Comet.

Halley's Comet continues to increase in brightness, though not so rapidly as during November and the first part of December. A photograph taken by Mr. Olivier on January 28th with an exposure of 54^m with the Crocker photographic telescope shows a narrow tail which can be traced about one degree from the head. Photographs taken with the Crossley reflector on February 4th and 5th show the inner portion of the tail as a narrow, fairly sharply defined cone. The nucleus is stellar, very sharp, and well defined, less than five seconds of arc in diameter.

A two-hour exposure made with the Crossley reflector on February 10th shows an entirely different form of tail, due doubtless to a sudden outburst of activity. The narrow, quiescent cone of February 4th and 5th has disappeared and given place to a tail made up of several fine streamers radiating from the head. These streamers can be traced fully 20′ from the head; the two longest streamers are straight, while the most southerly one is slightly curved. The Willard lens and Crocker telescope negatives for the same date show these changes as well, though less distinctly, owing to the smaller scale, and the tail is recorded for a distance of about 40′ from the head.

H. D. Curtis.

Physical Ephemeris of Halley's Comet.

Table I.

Date, 1910. Berlin Time.	T_1 P.S.T.	T_2 P.S.T.	T_3 P.S.T.	T_4 P.S.T.	P_r	A
Jan. 5.1	$7^h\ 23^m$	$5^h\ 2^m$	$6^h\ 23^m$	$6^h\ 1^m$	69° 32′	27° 48′
10.1	7 23	5 6	6 20	6 8	69 8	30 32
15.1	7 21	5 11	6 19	6 13	68 41	32 20
20.1	7 19	5 16	6 19	6 18	68 11	33 36
25.1	7 17	5 21	6 16	6 22	67 39	33 56
30.1	7 13	5 27	6 13	6 27	67 4	34 28
Feb. 4.1	7 10	5 32	6 10	6 33	66 24	34 58
9.1	7 4	5 38	6 5	6 37	65 39	33 0
14.1	6 58	5 43	6 0	6 42	64 35	32 18
19.1	6 53	5 49	5 55	6 47	63 38	30 44
24.1	6 46	5 54	5 49	6 52	62 13	28 38
Mar. 1.1	6 39	5 59	5 42	6 56	60 15	26 6
6.1	6 32	6 4	5 35	7 1	57 16	22 56
11.1	6 25	6 8	5 28	7 6	53 16	19 20
16.1	6 17	6 13	5 21	7 11	45 49	15 6
21.1	6 10	6 18	5 13	7 15	29 46	10 32
26.1	6 4	6 22	5 6	7 21	9 48	7 50
31.1	5 55	6 26	4 58	7 25	301 11	11 20
Apr. 5.1	5 47	6 31	4 50	7 31	279 56	18 56

The columns give in order (1) the date, (2) time of sunrise at Mount Hamilton, (3) time of sunset at Mount Hamilton, (4) time in the morning when Sun is 12° below horizon, (5) time in evening when Sun is 12° below horizon, (6) position angle of comet's tail, and (7) angle at comet between Earth and Sun. The second and third columns were taken by interpolation from the table given in *Publications of the Lick Observatory*, Vol. I. The sixth and seventh were computed from the ephemeris published in *The Observatory*, December, 1909, which was given in Berlin time for every fifth day. Perihelion passage was assumed to be 1910 April, 19.67.

Table II.

Greenwich Noon. 1910	$\alpha_\odot - \alpha_c$	P_r	Greenwich Noon. 1910	$\alpha_\odot - \alpha_c$	P_r
April 4	$+0^h\ 45^m\ 18^s$	282° 3′	Apr. 24	$+2^h\ 14^m\ 25^s$	258° 46′
8	1 3 50	272 29	28	2 28 57	257 18
12	1 22 15	266 54	May 2	2 40 30	256 11
16	1 40 34	263 19	6	2 47 18	255 30
20	1 58 5	260 42	10	2 44 20	255 13

Greenwich Noon. 1910	$\alpha_\odot - \alpha_c$	P_r	Greenwich Noon. 1910	$\alpha_\odot - \alpha_c$	P_r
May 11	$+2^h\ 40^m\ 10^s$	255° 27′	May 21	$-2^h\ 20^m\ 33^s$	99° 51′
12	2 35 12	255 41	22	3 9 43	103 37
13	2 27 27	256 23	23	3 47 26	106 15
14	2 15 48	256 41	24	4 16 57	107 59
15	2 0 44	257 40	25	4 34 42	109 7
16	1 39 36	259 9	26	4 49 25	109 53
17	1 10 22	261 23	27	4 59 38	110 26
18	+0 30 5	264 19	28	5 7 3	110 36
19	−0 21 49	90 3	29	5 12 11	111 13
20	1 18 2	95 29	30	−5 15 42	111 29

The above calculations are based on an ephemeris for Halley's Comet by Dr. SMART, which was published in *The Observatory*, November, 1909. It was assumed that the time of perihelion passage was 1910 April, 19.65.

MOUNT HAMILTON, CAL. CHAS. P. OLIVIER.

NOTE ON THE RADIAL VELOCITY OF *POLARIS*.

The radial velocity of the binary system of the triple system of *Polaris* decreased slowly from — 11.2^{km} per second at 1899.8 to about — 17.3 at 1908.7. The velocity observed with the Mills spectrograph at 1909.9 was approximately — 15.3. The minimum has, therefore, been passed, and the radial velocity of the center of mass of the binary system appears to be increasing rapidly. Radial velocity observations of the bright component of the *Polaris* system, made within the next few months, promise to have unusual weight in the determination of the period of the third member of the system around the center of mass of itself and the binary system.

W. W. CAMPBELL.

December 31, 1909.

NOTE CONCERNING THE RADIAL VELOCITY OF *PROCYON*.

We have radial velocities of *Procyon*, as determined with the Mills spectrograph, extending over thirteen years. This is one-third the revolution period deduced by Dr. AUWERS. As the observed radial velocities do not appear to have varied appreciably in a manner to accord with a period of forty

years, more or less, they seem to be in harmony with Dr. AUWERS's conclusion that the orbit plane of the system of *Procyon* is approximately tangent to the celestial sphere. However, it should be stated, with some reserve, that our observations appear to show a secondary variation of radial velocity whose double amplitude is probably less than 1.5 kilometers per second, and whose period is about seven years; but observations covering several additional years will be required to place this suspected variation beyond question.

W. W. CAMPBELL.

December 31, 1909.

DARIUS OGDEN MILLS, 1825-1910.

It is with deep regret that we here record the death of DARIUS OGDEN MILLS, on the evening of January 3, 1910, in his eighty-fifth year. Mr. MILLS was the donor of the two Mills spectrographs used in connection with the 36-inch refracting telescope; and the D. O. Mills Expedition from the Lick Observatory, University of California, located on the summit of Cerro San Cristobal, Santiago, Chile, is due solely to his generosity. Mr. MILLS was a member of the first Board of Trustees appointed by JAMES LICK to control the construction and equipment of the Lick Observatory, in which duty he gave freely of his time and mature judgment. Mr. MILLS's benefactions in support of higher education in its various phases and of organized charity were numerous and remarkable for their effectiveness.

GENERAL NOTES.

Ephemeris of Halley's Comet.—

(Continued from preceding number.)

Berlin Time.	α			δ	
1910 March 6.1	0^h	30^m	8^s	$+7°$	$57'$
11.1	0	26	23	8	0
16.1	0	22	34	8	2
21.1	0	18	30	8	4
26.1	0	14	12	8	5
31.1	0	9	38	8	4
April 5.1	0	4	50	8	1

Greenwich Noon.	α			δ	
April 4	0^h	5^m	38^s	$+8°$	$1'$
8	0	1	43	7	58
12	23	57	58	7	53
16	23	54	24	7	49
20	23	51	44	7	46
24	23	50	20	7	47
28	23	50	53	7	56
May 2	23	54	32	8	18
6	0	3	6	9	5
10	0	21	35	10	30
11	0	29	39	11	2
12	0	38	32	11	41
13	0	50	12	12	29
14	1	5	47	13	27
15	1	24	47	14	36
16	1	49	52	15	59
17	2	23	4	17	29
18	3	7	19	18	51
19	4	3	11	19	43
20	5	3	23	19	8
21	6	9	54	17	40
22	7	3	4	15	14
23	7	44	48	12	40
24	8	18	20	10	24
25	8	40	7	8	31
26	8	58	52	6	59
27	9	13	8	5	45
28	9	24	36	4	45
29	9	33	48	3	50
30	9	41	23	+3	15

The first portion of the ephemeris is taken from *The Observatory* for December, 1909, and is based on April 19.67, 1910,

as the time of perihelion; the second portion is from an ephemeris by Dr. SMART given in the same publication for November, 1909, and is based on April 19.65, 1910, as the time of perihelion passage.

Notes from "Science."—The prize of the Berlin Astronomical Society for the calculations of the path of Halley's Comet has been awarded to Messrs. COWELL and CROMMELIN.

The Paris Academy of Sciences has awarded the Pontécoulant prize to Professor E. W. BROWN for his work on the motion of the Moon.

The House of Representatives has passed a resolution ordering the disposal of certain government publications. A list of these publications was printed in *Science* for January 28th, and anyone desiring any of these may obtain them through the member of Congress from the district in which he resides. The publications of an astronomical nature are as follows: Astronomical Papers of the American Ephemeris, Vols. 5 and 6; Washington Astronomical Observations, 1881 to 1890; Coast Survey Reports, 1872, 1886 to 1897-8, 1906; Nautical Almanac, 1885 to 1909.

The same number of *Science* contains a report of the meeting, in Boston during convocation week, of Section A of the American Association for the Advancement of Science. Two papers on mathematical subjects and nineteen on astronomical subjects were presented before the meeting and the full titles are printed in the number of *Science* referred to.

The Naval Observatory.—In his annual message to Congress President Taft urged the appointment of a civilian astronomer to be director of the Naval Observatory at Washington, and pointed out the absurdity of the present arrangement, under which an officer of the navy, who usually has only an elementary knowledge of astronomy, has the direction of the affairs of the observatory. Changes are frequently made, so that by the time an officer begins to be familiar with his duties he is sent off to sea again.

Bills have been introduced into both houses of Congress in accordance with President Taft's recommendations, and it is

earnestly desired by astronomers and other scientific men of the country that the proposed change be brought about.

This is not the first time by any means that efforts of this kind have been made, but the bills have always been killed heretofore, chiefly through the influence of the navy men. They naturally oppose any legislation which has for its object the taking away of something which they now have, and it is presumed that they will present a united opposition to the present legislation. The astronomers of the country must make a determined effort in favor of the bills, and it is suggested that the members of the Astronomical Society of the Pacific can help by writing to their Representatives and Senators, calling attention to the desirability of the proposed legislation. The one and all sufficient reason why this change in the directorship of the observatory is desired is, simply, that the scientific efficiency of the institution may be increased.

S. D. T.

Eclipse of the Sun.—No government expedition will, Reuter's Agency is informed, be dispatched from this country to observe the eclipse of the Sun, owing to the unfavorable conditions and the remoteness of the region in which it will be visible. The eclipse will take place on May 8th, and will be visible only in Tasmania. The Sun's altitude being only eight degrees, and the totality (the period of which is $3\frac{1}{2}^{m}$) occurring shortly before sunset, the chances of obtaining good observations are doubtful. The work of officially observing the eclipse will be left to Australian observers.

The joint committee of the Royal Society and the Royal Astronomical Society have been in communication with the observatory at Melbourne and are assisting with instruments, etc. An eclipse committee has been formed to organize expeditions to observe in Tasmania. The Australian expeditions will probably go to Port Davey, the best available port, which is two days' journey from Melbourne and about fourteen hours from Hobart. The neighborhood from which the eclipse will be observed is generally hilly and difficult of access by land or sea. It has been arranged that Mr. BARACCHI (director of Melbourne Observatory), Mr. J. M. BALDWIN (chief assist-

ant), and Mr. C. J. MERFIELD will form the observing contingent from Melbourne Observatory.—*London Standard.*

Additions to Library.—The Library Committee announces the purchase of the following named books, which have been added to the library:—

BALL—Mathematical Recreations and Essays.
BERRY—History of Astronomy.
CHAMBERS—Story of the Comets.
CLERKE—History of Astronomy during the Nineteenth Century.
CLERKE—Problems in Astrophysics.
DOLMAGE—Astronomy of Today.
GIBSON—Scientific Ideas of Today.
NEWCOMB—Reminiscences of an Astronomer.
NEWCOMB—Sidelights on Astronomy.
POOR—The Solar System.
WALLACE—Man's Place in the Universe.
YOUNG—Manual of Astronomy.

Changes in the Mounting of the Crossley Reflector.—The Crossley reflector was dismounted on January 20th and the bearings of the declination and polar axes taken down to San Jose to be bored out for the new roll systems. The new roller bearings are of the anti-friction type installed with such good results in the Mills reflector at Santiago, Chile, in 1906.[1] In addition to the roller system, the declination axis is provided with ball thrust rings, and the weights, levers, and friction wheels have been removed from the polar axis, being no longer necessary. Only three or four pounds is necessary to move the telescope in declination and about ten pounds in the right ascension component; the total weight of the moving parts is about six tons.

A new finder has been added to the instrument, having a focal length of seventeen feet, seven and a half inches, making it possible to guide directly on a comet or other rapidly moving object; the slow motion in declination has been replaced with a new one of convenient access from either the eye end or the lower end of the telescope.

[1] *Publication A. S. P.*, October, 1907.

Owing to delays in the boring out of the large bearings, the remounting was not completed till the night of January 30th.

HEBER D. CURTIS.

The unusual delay in the appearance of the present number of the *Publications* is due chiefly to the loss of some of the proofs in the mail.

NEW PUBLICATIONS.

Annuario Astronomico pel 1910. Publicato dal R. Osservatorio di Torino. Torino. 1910. 8°. 98 pp. Paper.

Bahnelemente der kleinen Planeten für 1910. Berlin. 1909. 8°. 107 pp. Paper.

BERGSTRAND, ÖSTEN. Sur le calcul de la réfraction differentielle en distance et en angle de position. Upsala. 1909. 4°. 46 pp. Paper.

BIRCK, OTTO. Das photographische Helligkeits-verhältnis der Sonne zu Fixsternen. Göttingen. 1909. 4°. 97 pp. Paper.

BOSS, LEWIS. List of 1,059 standard stars for 1910. Albany. 1909. Folio. 24 pp. Paper.

BRÜCK, PAUL. Sur une étoile filante. Paris. 1909. 8°. 5 pp. Paper.

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WEMRICH, MORRIS FRANCIS. Rutherfurd photographs of stars surrounding *β Cygni*. New York. 1909. 8°. 34 pp. Paper.

Minutes of the Meeting of the Board of Directors of the Astronomical Society of the Pacific, Held at Chabot Observatory, Oakland, California, January 29, 1910.

In the absence of President Campbell, Mr. F. Morse, Third Vice-President of the Society, presided.

The minutes of the preceding meeting were approved.

On motion of Professor C. Burckhalter, the name of Elam C. Brown was presented for membership. Carried.

On motion of Professor R. T. Crawford, the Treasurer was authorized to expend the sum of $30 from the General Fund for the payment of clerical help in the preparation of a general index to the first twenty volumes of the *Publications* of the Society. It was understood that this work was being done under the supervision of Professor R. G. Aitken, of Lick Observatory. Carried.

A resolution was introduced by Professor Crawford, representing the Faculty of the University of California, calling upon the Astronomical Society of the Pacific to nominate, through its President, a committee of three to co-operate with similar committees from other scientific bodies on the Pacific Coast, in the formation of an affiliated organization, for purposes of mutual interest and advantage. The motion was carried, and President Campbell was instructed to appoint such a committee.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, Held at Chabot Observatory, Oakland, California, January 29, 1910, at 8 o'Clock.

In the absence of Dr. W. W. Campbell, President of the Society, Mr. F. Morse, Third Vice-President, presided. He introduced as speaker of the evening Professor R. T. Crawford of the University of California, who read a timely and attractive paper on Halley's Comet, illustrated with lantern slides.

The great popular interest felt in the approach of this remarkable object, coupled with the unexpected appearance of Comet *a* 1910 in the western sky during the latter days of January, attracted an audience large enough to comfortably fill the lecture room of the observatory, and the speaker was followed with close attention. He briefly outlined the known history of the comet, told the romantic story of its recognition and the prediction of its return by Halley, indicated its positions and appearance during the coming spring months and allayed the fears, if any existed, of those who feared disaster from collision of the comet with the Earth.

By courtesy of Professor BURCKHALTER, of Chabot Observatory, the telescope of the observatory was placed at the disposition of members and their friends between the hours of 7 and 8 P. M. and many took advantage of the opportunity to obtain a view of the historic wanderer —still a misty blur in the far southwest.

The meeting was one of the most successful and enjoyable held by the Society for many years.

OFFICERS OF THE SOCIETY.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience.. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents: of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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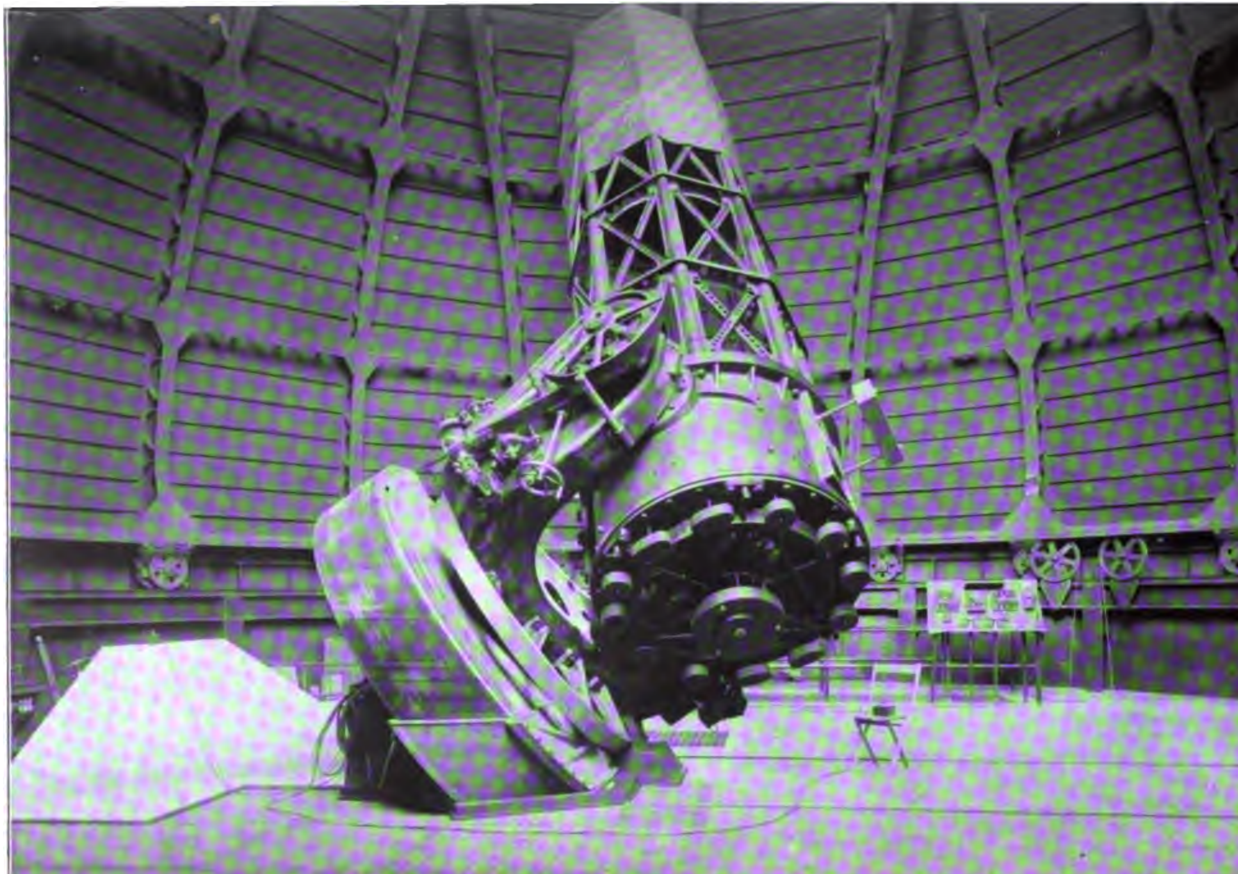

SIXTY-INCH REFLECTOR, MOUNT WILSON SOLAR OBSERVATORY.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XXII. San Francisco, California, April, 1910 No. 131

A STUDY OF SPECTROSCOPIC BINARY STARS.[1]

(Abstract of retiring President's Address, delivered at the annual meeting of the Astronomical Society of the Pacific, on the evening of March 26, 1910.)

By W. W. Campbell.

The number of known spectroscopic binary stars increased from 136 on January 1, 1905, the epoch of the First Catalogue of Spectroscopic Binaries, up to 303 on January 1, 1910. The number of fairly well-determined orbits increased in the same period from fewer than twenty to about seventy. To meet the pressing needs of observers and computers, but more especially to furnish an improved basis for the general study of binary stars, I have prepared the manuscript for a Second Catalogue of Spectroscopic Binary Stars, which will be issued in the course of a few weeks. It aims to list all binary systems discovered by means of the spectrograph at this and other observatories prior to the epoch January 1, 1910, and to include the principal facts concerning these systems available on March 15, 1910. These facts refer to the periods of revolution in the orbits, the eccentricities of the orbits, the magnitudes of the orbits, the relations concerning the masses of the bodies involved, etc.

During the preparation of the tables for publication, a study was made of those binary systems for which periods and other elements of the orbit have been determined, considering them from various points of view.

[1] The results of this study of spectroscopic binary stars, as outlined in the present abstract, were presented in the Silliman Lectures, delivered in Yale University, January 24 to February 2, 1910, by Director W. W. Campbell.

It should be explained, by way of preface, that Harvard College Observatory formulated several years ago a most useful system of classification for stellar spectra, in which the types corresponding to advancing stages of development are represented by the capital letters Q, O, B, A, F, G, K, and M; Q and O representing the earliest types of stellar life, and M the oldest types. Gradations within the types are described by means of steps expressed in numerals or lower-case letters. For example, a star representing a stellar state midway between B and A is denoted by B5. This Harvard classification has been utilized in the present and other studies with advantage.

TABLE I.—SPECTROSCOPIC BINARIES, *O* AND *B* TYPES.

H. R.	Star	Types	Period	e	$a \sin i$	$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
779	δ *Ceti*	B2	short						
1088	τ_5 *Eridani*	B8	short						
1347	υ_4 *Eridani*	B9	short						
2781	29 *Can. Maj.*	Oe	short						
4118	δ *Antliæ*	B9	short						
4662	γ *Corvi*	B8	short						
6027	ν *Scorpii*	B3	short						
7248	Υ *Aquilæ*	B8	short						
			d						
8238	β *Cephei*	B1	0.19	small	45,000	0.0001			
2294	β *Can. Maj.*	B1	0.25	0.1±	33,500	0.00002			
1567	π_5 *Orionis*	B3	0.87						
3129	ν *Puppis*	B1p	1.45	(0.)	6,100,000		17.1	17.1	
6247	μ *Scorpii*	B3p	1.45		4,586,000		7.2	7.2	
5944	π *Scorpii*	B2p	1.57						
6431	u *Herculis*	B3	2.05	0.05	2,800,000	0.205	6.8	2.6	0.39
6431_1	"		2.05	"	7,120,000	3.43			
1811	ψ *Orionis*	B2	2.53	0.06	4,995,100	0.780	5.53	4.19	0.76
1811_1	"		2.53	"	6,570,000	0.343			
8523	2 *Lacertæ*	B5	2.62	0.02	2,890,000	0.141	0.87	0.71	0.8
8523_1	"		2.62	"	3,550,000	0.026			
8001	57 *Cygni*	B3	2.85						0.96
936	*Algol*	B8	2.87	0.04	1,600,000	0.200	0.44	0.22	0.5
1239	λ *Tauri*	B3	3.95	0.	3,300,000	0.089			
5056	α *Virginis*	B2	4.01	0.10	6,930,000	0.833	9.6	5.8	
5056_1	"		4.01	"	11,400,000	3.68			
226	ν *Androm.*	B3	4.28	0.	4,299,000	0.173			
1131	o *Persei*	B1	4.42	0.	7,100,000	0.578			
6527	λ *Scorpii*	B2	5.6						
1852	δ *Orionis*	B	5.73	0.10	7,906,600	0.601			
8926	BD+57.2748	B3	6.07						
1542	9 *Cameloopard.*	B	6.33						

TABLE I.—SPECTROSCOPIC BINARIES, *O* AND *B* TYPES—*Continued.*

H. R.	Star	Types	Period d	e	$a \sin i$	$\frac{m^3_1 \sin^3 i}{(m+m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
3623	*κ Cancri*	B8	6.39	0.15	5,890,000	0.200			
3659	*a Carinæ*	B3	6.74	0.18	1,960,000	0.007			
5984	*β Scorpii*	B1	6.9						
1788	*η Orionis*	B1	7.99	0.02	15,901,000	2.51	11.2	10.6	0.95
1788_1	"		7.99	"	16,750,000	2.15			
5231	*ξ Centauri*	B2p	8.02						
1552	*π_4 Orionis*	B3	9.52	0.03	3,393,000	0.017			
7790	*a Pavonis*	B3	11.75	0.01	1,170,000	0.0005			
7106	*β Lyræ*	B2p	12.91	0.07	33,000,000	9.7	9.6	20.9	2.2
7106_1	"		12.91	"	15,800,000	1.0			
1713	*β Orionis*	B8p	21.90	0.30	1,108,900	0.0001			
2653	*o_2 Can. Maj.*	B5p	24.3±	0.	1,670,000±	0.0003±			
1952	BD — 1.1004	B3	27.16	0.76	22,380,000	0.607			
1899	*ι Orionis*	Oe5	29.14	0.75	28,907,000	1.14			
6084	*σ Scorpii*	B1	30.±						
5190	*ν Centauri*	B2	31.±						
3734	*κ Velorum*	B3	116.65	0.19	73,200,000	1.15			
496	*φ Persei*	Bp	126.5	0.43	42,298,000	0.189			
2159	*ν Orionis*	B2	131.4						
1910	*ζ Tauri*	B3	138.	0.18	27,900,000	0.046			
154	*π Androm.*	B3	143.72	0.58	76,790,000	0.876			
6812	*μ Sagittarii*	B8p	180.2	0.44	143,500,000	3.63			
			y						
936_1	*Algol*	B8	1.90	0.0	89,000,000	0.060			

The first table lists the spectroscopic binaries of O and B types,—stars effectively young in age,—whose periods of revolution have been fairly well determined, arranged in the order of their periods. The first column gives the serial number in the Harvard Revised Photometry.[1] Except in the case of the last star on the list, which refers to the orbit of the center of mass of the binary system of *Algol* around the center of mass of itself and a suspected third body, the periods are all under one-half year, and two thirds of them are under ten days in length. An inspection of column "*e*," which lists the corresponding eccentricities, shows convincingly that the eccentricities are small for the shorter periods and relatively large for the longer periods; that is, the orbits are more nearly circular for the short-period binaries than for those whose periods are relatively long. The second column from the last quotes the mass of the brighter member of each system, multiplied by the cube ($\sin_3 i$) of the sine of the inclination

[1] *H. C. O. Annals*, Vol. L.

of its orbit, in terms of the Sun's mass as unit, for which the velocities of the *two members* of the system have been observed spectrographically. The next to the last column quotes similarly the mass of the fainter member of the system. The last column contains the ratio of the mass of the fainter member to that of the brighter member. It is characteristic of orbits, as determined by means of the spectrograph, that the inclination of the orbit plane to the line of sight cannot be determined. It will be seen that the masses of the two bodies, even after they are multiplied by the sine-cube of the inclination, are, on the whole, greater than the mass of the Sun. Attention is also called to the fact that in the case of *Beta Lyræ* alone is the brighter member of smaller mass than the fainter.

TABLE II.—SPECTROSCOPIC BINARIES, *A* TYPES.

H. R.	Star	Types	Period	e	$a \sin i$	$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
104	BD + 43.92	A2	short						
897	θ_1 *Eridani*	A2	short						
1380	64 *Tauri*	A2	short						
5971	Z *Cor. Bor.*	A	short						
			d						
2124	μ *Orionis*	A2	0.77						
815	RZ *Cassiop.*	A	1.20		1,170,000	0.046±	0.646	0.356	0.55
1497	τ *Tauri*	A	1.50	0.08	916,130	0.0136			
5586	δ *Libræ*	A	2.33	0.05	2,450,000	0.110	0.84	0.61	0.70
	U *Cephei*	A	2.49						
2890	α_1 *Gemin.*	A	2.93	0.01	1,279,000	0.0097			
7326	U *Sagittæ*	A	3.38						
1568	7 *CameloPard.*	A2	3.88						
2088	β *Aurigæ*	Ap	3.96	0.00	6,000,000		2.16	2.16	1.0
6324	ϵ *Herculis*	A	4.02	0.07	3,000,000	0.067			
6324₁	"		4.02	"	4,286,000	0.194			
2891	α_2 *Gemin.*	A	9.22	0.50	1,485,000	0.0015			
4072	BD + 66.664	A	11.6	large					
7710	θ *Aquilæ*	A	17.11	0.69	7,665,000	0.061	0.311	0.276	0.89
7710₁	"		17.11	"	8,610,000	0.087			
5793	α *Cor. Bor.*	A	17.36	0.33	7,600,000	0.059			
5054	ζ *Urs. Maj.*	Ap	20.54	0.50	17,500,000		2.0	2.0	1.0
8178	β *Equulei*	A	22.7±						
4295	β *Urs. Maj.*	A	27.16	0.79	1,774,000	0.0003			
622	β *Triang.*	A5	37.0±						
5291	α *Draconis*	A	51.38	0.40	30,000,000	0.42			
4689	η *Virginis*	A	71.9	0.33	25,500,000	0.126			
15	α *Androm.*	A	96.7	0.51	33,000,000	0.155			
553	β *Arietis*	A5	107.0	0.88	22,880,000	0.042	0.17	0.17	1.0

TABLE II.—SPECTROSCOPIC BINARIES, *A* TYPES—*Continued.*

H. R.	Star	Types	Period y	e	$a \sin i$	$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
2421	*γ Gemin.*	A	3.5±	large					
2491	*Sirius*	A	49.4	0.59					

Table II records corresponding facts for the A-type stars; that is, those which are believed to be somewhat further along in their process of development. The last star on the list, *Sirius,* it is well known, was discovered to be a visual binary in 1862. It is included in the list, technically, for the reason that the spectrograph has measured the velocity of the bright star in the system and found it to be variable, corresponding with the well-known visual orbit. In this list again the eccentricity is seen to be, in general, a function of the period of revolution. Short periods have small eccentricities, implying orbits nearly circular. The ratio of the masses is again equal to or smaller than unity.

TABLE III.—SPECTROSCOPIC BINARIES, *F* TYPES

(Cepheid variables not included.)

H. R.	Star	Types	Period d	e	$a \sin i$	$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
2788	R *Can. Maj.*	F	1.14						
142	13 *Ceti*	F	2.08	0.06	981,000	0.0087			
5986	*θ Draconis*	F8	3.07	0.01	990,000	0.0041			
424	*α Urs. Min.*	F8	3.97	0.13	164,500	0.00001			
	Z Herculis	F	3.99						
7056	*ζ Lyræ*	F	4.30	0.00	3,030,000	0.060			
6596	*ω Draconis*	F5	5.28	0.01	2,632,000	0.0261			
8315	*κ Pegasi*	F5	6.±						
8430	*ι Pegasi*	F5	10.21	0.01	6,740,000	0.117			
3852	*o Leonis*	F5p	14.50	0.02	10,775,000	0.238	1.302	1.116	0.86
3852₁	"		14.50	"	12,571,000	0.378			
2693	*δ Can. Maj.*	F8p	275.±	0.0	5,650,000	0.0001			
6927	X *Draconis*	F8	281.8	0.42	63,000,000	0.126			
			y						
8123	*δ Equulei*	F5	5.7	0.36					
424₁	*α Urs. Min.*	F8	11.9	0.35	166,800,000	0.0098			
3185	*ι Argus*	F5	long						

In Table III we have F-type stars, representing a still older stage. Again, the short periods have orbits of small eccentricity, and the long periods, of great eccentricity.

TABLE IV.—SPECTROSCOPIC BINARIES, TYPES *G* TO *M* INCLUSIVE.

(Cepheid variables not included.)

H. R.	Star	Types	Period	e	$a \sin i$	$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
			d						
8961	λ *Androm.*	K	20.54	0.11	1,900,000	0.0006			
1708	*Capella*	G	104.02	0.02	36,847,900	0.184	1.19	0.94	0.79
1708_1	"		104.02		46,430,000	0.369			
429	γ *Phœnic.*	K5	190.±						
6148	β *Herculis*	K	410.58	0.55	60,280,000	0.052			
5235	η *Bootis*	G	489.14	0.18	56,010,000	0.0293			
			y						
4375	ξ *Urs. Maj.*	G	1.8						
8650	η *Pegasi*	G	2.24	0.16	157,800,000	0.234			
7776	β *Capric.*	G	3.77	0.44	377,000,000	1.13			
6134	α *Scorpii*	Map	5.8	0.20	60,490,000	0.0020			
6752	70 *Ophiuchi*	K	87.86	0.50					
99	α *Phœn.*	K	long						
539	ζ *Persei*	K	long						
549	ξ *Piscium*	K	long						
854	τ *Persei*	Gp	long						
915	γ *Persei*	Gp	long						
1066	f *Tauri*	K	long						
2216	η *Gemini*	Ma	long						
2296	δ *Colum.*	G5	long						
2553	τ *Puppis*	K	long						
2854	γ *Can. Min.*	K	long						
4301	α *Urs. Maj.*	K	long						
8079	ξ *Cygni*	K5	long						
8115	ζ *Cygni*	K	long						

Table IV lists the G and M binary types for which orbital data are available. It will be recalled from the preceding illustrations that about two thirds of the O and B types listed have periods of less than ten days; that half the A types have periods of less than ten days; that half the F types have periods of less than ten days; and it is interesting to note that there are no known binaries of G-M types whose periods are less than twenty days. The eccentricities in column *"e"* are again seen to be functions in general, of the length of period.

TABLE V.—SPECTROSCOPIC BINARIES—SPECTRAL TYPES, PERIODS, AND ECCENTRICITIES.

	"short"	0^d — 5^d	5^d — 10^d	10^d +	Years "long"
O and B types...	8	15	10	14	1
Period	short	$2^d.4$	$6^d.9$	$73^d.2$	$1^y.9$
Eccentricity		(10) 0 .04	(5) 0 .10	(11) 0 .34	(1) 0 .0

TABLE V.—SPECTROSCOPIC BINARIES—SPECTRAL TYPES, PERIODS, AND ECCENTRICITIES —*Continued.*

	"short"	0^d — 5^d	5^d — 10^d	10^d +	Years	"long"
A types	4	10	1	11	2	
Period	short	$2^d.65$	$9^d.2$	$43^d.7$	$26^y.45$	
Eccentricity		(5) 0 .04	(1) 0 .50	(8) 0 .55	(1) 0 .59	
F types	0	6	2	4	2	1
Period		$3^d.1$	$5^d.6$	$145^d.1$	$8^y.8$	long
Eccentricity		(4) 0 .05	(1) 0 .01	(4) 0 .11	(2) 0 .36	
G to M types	0	0	0	3	7	13
Period				$104^d.85$	$16^y.3$	long
Eccentricity				(2) 0 .06	(6) 0 .34	
Total	12	31	13	32	12	14
Mean period		$2.^d59$	$6^d.91$	$75^d.0$	$15^y.53$	
Mean eccentricity		(19) 0 .05	(7) 0 .14	(25) 0 .35	(10) 0 .33	

The relations existing between the spectral types, lengths of period, and eccentricities are presented in a more condensed form in Table V. The table is double entry, with the lengths of period classified in the first line, and the types, average periods, and average eccentricities in the following twelve lines. It will be noted that there is a relation between average periods and average eccentricities; the eccentricity increases in value with the increase of period. The decrease in the number of short-period binary systems, with advancing stellar age, is graphically evident from the zero in the F division and the three zeros in the G-M division. The facts referred to are brought out even more forcibly in the last three lines of the table. The second line from the last, "total," sums up the number of binaries in all the four types. The next to the last line gives the average periods of these binary systems. The last line gives the average eccentricities of all those stars in these divisions for which the eccentricities have been determined, the number of eccentricity values in each case being indicated by the numbers in parentheses. Thus there are thirty-one binaries whose definitely determined periods, lying between zero days and five days, average 2.59 days in length. For nineteen of these the eccentricities have been determined, and the average value is 0.05. The close relationship existing between length of period and eccentricity of orbit is so apparent that we need not further study the tabulations.

The period of revolution is a function of the spectral type, and the eccentricity is a function of the period. What is the

significance of these facts? Let us recall that DARWIN and POINCARÉ studied the origin of binary stars from theoretical considerations, and came to the conclusion that a condensing nebulous mass, rotating on its axis constantly faster and faster, to keep pace with loss of heat through radiation, should eventually separate into two nebulous masses revolving around their mutual center of mass. These two masses would, in the beginning, be revolving in contact in an orbit essentially circular. With advancing time, tidal disturbances should cause the two bodies to draw apart rapidly at first, and less rapidly later.

In the spectroscopic binary systems described in this address have we not a tolerably complete sequence of orbits illustrative and confirmatory of the DARWIN-POINCARÉ hypothesis? The short-period orbits should be circular or nearly so, and should appertain to stars of early spectral types; the longer periods should, in general, attach to the more eccentric orbits and the older spectral types; and these are the facts established by actual observation of binary systems. There are many lines of supporting and confirmatory evidence. Let us consider a few from the *Algol* variable stars. Many of the *Algols* have been observed photometrically with great accuracy, by ROBERTS and others, and certain characteristics of these systems have been deduced from a study of their light curves. Only two *Algol* stars have had their orbits determined from a satisfactory series of spectrographic velocity measurements. The main

TABLE VI.—VARIABLES OF ALGOL TYPE.

No. of stars.	Periods in days.	No. of stars.	Periods in days.	No. of stars.	Periods in days.
9	0 to 1	1	7 " 8	1	31
11	1 " 2	1	8 " 9	1	32
17	2 " 3	2	9 " 10	1	35
12	3 " 4	0	10	1	262
4	4 " 5	0	11	——	
4	5 " 6	2	12	72	
4	6 " 7	1	13		

5 stars *B* type spectrum.
13 " *A* " "
2 " early *F* type spectrum.
Others unknown spectrum.

2 spectroscopic orbits,—

$e = .03$	$P = 2^{d}.87$
$e = .05$	$= 2\ .33$
Means, .04	2 .6

Several photometric orbits, all nearly circular; short periods.

TABLE VI.—VARIABLES OF ALGOL TYPE—*Continued.*

DENSITIES.

	No. of stars.	Average density.
ROBERTS	4	0.13 ⊙
RUSSELL	17	.20 ⊙
RISTENPART	10	.07 ⊙

facts concerning these systems are referred to in Table VI. Seventy-two *Algol* stars are known, not counting a considerable number of suspects. The numbers having periods of certain lengths are tabulated in columns 1 and 2. There are nine whose periods are less than one day; forty-nine whose periods are less than four days; twelve whose periods are between four and seven days; and only eleven of periods longer than seven days. The greater number of *Algols* are so faint that their spectral types have not been determined by Harvard College Observatory or elsewhere. Of those whose types are known, five stars are of B type, thirteen of A type, and two of early F type. None have been recognized as of late F, or of G-M types. The eccentricities and periods of the two spectrographically determined orbits have the mean values—

$$e = 0.04$$
$$P = 2.6 \text{ days}$$

Of the several photometric orbits determined the eccentricity is thought to be very small, with two or three exceptions. ROBERTS, RUSSELL, and RISTENPART have investigated the average density of four, seventeen, and ten *Algol* stars, respectively, with the results, as quoted, that the average densities are less than one fifth that of the Sun's density. From the clews which we have here and there as to the masses of *Algol* stars, we can have no reasonable doubt that they are in general attenuated bodies, with diameters greatly exceeding the Sun's diameter.

Considering all these facts, it is easy to arrive at an apparently extremely important conclusion as to why we have more than a few *Algol* variables.

The two members of an *Algol* system are in general so near each other and so large in diameter that eclipses occur with great ease: they are observable by those of us who are not situated exactly in the plane of the orbit; the eclipses last a long time, so that even the unsystematic observations of the past have readily detected variable brightness. As the two

members of a system grow further and further apart, corre sponding to the longer periods as tabulated in column 2, the number of eclipsing pairs decreases very rapidly, as indicated in column 1. *Algol* stars of types G-M appear not to have been observed for the reasons that the binary stars of these types have their components relatively far apart; and eclipses would be of relatively short duration both because the stars are widely separated and because they are of smaller diameter, being more condensed. The observer would have to be situated very closely in the plane of the orbit in order to witness an eclipse, and his chances for observing an eclipse would be small, as compared with eclipses of close systems.

Closely related to the *Algols* are the *β Lyræ* variables. These appear to be in fact an extreme type of *Algol* star, whose two component stars are highly attenuated and revolving nearly or quite in contact. Their spectra are of early types, and their orbits are circular or nearly so, in so far as they have been investigated.

TABLE VII.—VISUAL DOUBLE STARS.

Star.	Period. y	e	Spectrum.
δ *Equulei*	5.70	0.36	F5
13 *Ceti*	7.42	0.74	F
κ *Pegasi*	11.37	0.40	F5
ε *Hydræ*	15.70	0.68	F8
β 883	16.35	0.48	
ζ *Sagittarii*	21.17	0.18	A_2
β 612	22.8	0.48	A
9 *Argus*	23.3	0.68	F8
82 *Ceti*	24.00	0.15	K
42 *Comæ*	25.56	0.46	F5
	17.33	0.461	

Star.	Period. y	e	Spectrum.
85 *Pegasi*	25.70	0.43	G
β *Delphini*	27.66	0.36	F5
Σ 3121	34.00	0.33	
ζ *Herculis*	34.53	0.46	G
20 *Persei*	36.00	0.75	F
β 581	41.2	0.53	
η *Cor. Bor.*	41.51	0.28	G
ξ *Scorpii*	44.5	0.77	F8
μ *Herculis*	45.39	0.21	
β 416	45.90	0.62	K5
	37.64	0.474	

TABLE VII.—VISUAL DOUBLE STARS—*Continued.*

Star.	Period. y	e	Spectrum.
Σ 2173	46.0	0.20	G
Sirius	49.4	0.59	A*
οΣ 298	52.0	0.58	
β 513	53.0	0.35	A_2
γ *Andr.* BC	55.0	0.82	**
τ *Cygni*	53.0±	0.31±	F
ζ *Cancri*	59.1	0.38	F
ξ *Urs. Maj.*	59.8	0.41	G
99 *Herculis*	64.5	0.81	F8
οΣ 235	66.0	0.50	F
	55.8	0.495	

Star.	Period. y	e	Spectrum.
8 *Sextantis*	68.8	0.60	A_2
γ *Cor. Bor.*	73.0	0.48	A
οΣ 234	77.0	0.30	
οΣ 400	81.0	0.46	
α *Centauri*	81.2	0.53	G, K_5
γ *Centauri*	88.0	0.80	A
70 *Ophiuchi*	88.4	0.50	K
οΣ 387	90.0	0.60	
οΣ 285	97.9	0.60	
φ *Urs. Maj.*	99.7	0.44	A_2
	84.4	0.531	

Star.	Period. y	e	Spectrum.
Σ 3062	104.6	0.45	F
ω *Leonis*	116.2	0.54	G
Σ 228	123.1	0.31	
ξ *Bootis*	148.5	0.54	K5p
γ *Cor. Aus.*	152.7	0.42	F8
Σ 2	166.2	0.40	A
O_2 *Eridani* BC	180.0	0.13	***
25 *Cam. Ven.*	184.0	0.75	F
Σ 2107	186.2	0.39	
γ *Virginis*	194.0	0.90	F
	155.6	0.483	

Let us examine Table VII, giving data for fairly well-determined orbits of visual double stars. Here is a list of fifty stars, in groups of ten. The periods, eccentricities, and spectral

* Star A = — 1.5, F type. Star B = 9, yellow.

** Star A = 2.28, K type. Star BC = 5.08, blue.

*** Star A = 4.5, G5. Star BC = 9, blue.

types as far as known are quoted for the individual star, and the means by tens are given for the periods and eccentricities. It will be noted that in these widely separated systems there is not a single O or B type, representing the early stages of binary existence. There are a few A types, but the major number are of the advanced F type and G and K types. I suspect the K, M, and N types are not more fully represented for the reason that in these old-age systems the two components are in general so far apart that the periods of revolution are many hundreds or thousands of years. It will be recalled that double-star observations made since the day of Sir WILLIAM HERSCHEL enable us to determine satisfactorily the orbits of short-period double stars only. In fact, the longest period in the present list of fifty is 194 years. In this connection I am pleased to refer to the work of Professor SEE, in the early 1890's, on the evolution of stellar systems, wherein he calls attention to the high eccentricities of visual double-star orbits, and elaborates the theory that the visual binary systems have been evolved, with increasing periods and eccentricities, through the action of tidal friction. In this table, arranged in the order of length of periods, there is some evidence of progression in the value of the eccentricity, but this is not very definite. These eccentricities of visual orbits, varying from 0.43 to 0.54, are, however, appreciably larger than the average eccentricity, 0.34, of the thirty-five spectroscopic binary systems of longest period. To repeat, the spectroscopic binaries with periods between zero and five days have eccentricity 0.05; those with periods between five and ten days, eccentricity 0.14; those with periods between ten days and a year, 0.35; those with periods between one year and eighty-eight years,—average, 15½ years,—eccentricity 0.33; and fifty visual double-star orbits, with periods between five and 194 years,—average, seventy-two years,—have average eccentricity 0.49.

There are many other equally interesting considerations attaching to this subject, but time forbids presenting more than one. A paper of considerable length on the subject is ready for publication in the *Lick Observatory Bulletin*.

The remaining consideration relates to the question of masses in binary systems. Except in the case of *Algol* stars, and here only on the assumption that we are in the plane of the

orbit, it is not possible to determine from spectrographic observations alone the masses in binary systems. The cube of the sine of the unknown inclination of the orbit to the line of sight is involved. However, it can be shown that in a very great number of such systems the average value of i would be 57°.3 and of $\sin^3 i$ 0.59. If we insert in the tables this value of $\sin^3 i$, in the seventeen cases for which we have been able to determine the values of $m \sin^3 i$ and $m_1 \sin^3 i$ (that is, the systems in which both spectra are visible and have been measured), we find that the masses of the components in the majority of cases are much greater than the Sun's mass. Further, the masses, on the whole, are not very unequal. For those having unequal masses, the fainter component has the smaller mass, except in the one case of *Beta Lyræ*. In this one case the masses are so unequal and the two components are so close together that it is not impossible, as MEYERS has suggested, the actual relative intensity of the two bodies is reversed by an absorbing medium which completely encloses the binary system and which, owing to the greater attractive power of the more massive component, is more condensed around that component.

In connection with these facts let us consider three others.

Sixty-three of the binary systems contained in the Catalogue of 303 systems show more or less clearly the existence of two spectra in each. Of these sixty-three, thirty-one are of O and B types, twenty-three of A type, five of F type, three of G type, one of K type, and none of M type: a clear and decided preference for the early types. In each one of these cases, in which one spectrum is weaker than the other, the weaker spectrum refers to the less massive body, so far as measurements are available, except in the case of *Beta Lyræ*.

Harvard College Observatory has catalogued forty-one stars whose spectra are composite,—that is, each spectrum is the sum of two spectra. It has not been possible to classify the fainter spectrum in all cases, but of those completely described the fainter spectrum is of an earlier type than the brighter spectrum, with, I believe, seven or eight exceptions; and in two of these the spectral types differ but slightly.

It is characteristic of the well-known visual double stars of unequal magnitude that the fainter component is bluer than

the brighter component; that is, the fainter component has the earlier type of spectrum. There appear to be a few exceptions to this rule.

All these facts appear to be in harmony with the following hypothesis: The nebula which gives rise to a binary system, through fission, divides into two masses, usually not very unequal, and the spectra at first are substantially of the same type. Because the masses are nearly equal, the chances for observing both spectra are favorable. In general, the more massive component increases in brilliancy and lives its life more rapidly than the component only slightly less massive. As Sir WILLIAM HUGGINS suggested rather casually many years ago, this may be due to the influence of the greater internal gravitational power of the more massive star. Materials are drawn more powerfully toward the center of this star, and in consequence heat and light are generated and radiated more rapidly. With advancing time, the fainter component, living its life less rapidly, is lost in the rays of the more luminous primary, until such time as the separation of the components enables them to be observed as a visual double star, with the less developed secondary several visual magnitudes fainter than the more massive primary.

We can all recall a few exceptions, which apparently contradict this hypothesis. For example, the faint companion of *Sirius*, having less than half the mass of the primary, is said to be of spectral type further advanced than that of the primary. It should also be stated that LEWIS, of Greenwich, discussing meridian circle and micrometer observations of certain prominent double stars, has deduced a greater mass for the fainter companion than for the more brilliant yellow primary, in nearly all cases investigated. Professor BOSS has informed me, however, that his investigations of double stars of this class reverse LEWIS's conclusions, and that the blue companions in double stars are in reality either equal to or less massive than their primaries of older spectral type.

The spectrographic observations at the Yerkes Observatory have established that one star in three, certainly, of the very early-type spectra, is a spectroscopic binary. The Lick Observatory observations have been confined more largely to the middle and later stellar types, with the result that one

star in six, more or less, is proved to be a spectroscopic binary. These different ratios seem to be due to the fact that the early types are of short periods, which makes their discovery easier and more prompt. They likewise are characterized by a higher range of velocity variations. The spectroscopic binaries of older types revolve in larger orbits with longer periods, and change their velocities more slowly. They are on these accounts more difficult to discover. Binaries of the early types may or may not actually be more numerous than those of the later types. AITKEN's double-star investigations have shown that one star, on the average, out of every eighteen is a visual binary. As explained in AITKEN's paper,[1] the close binary systems are more numerous than those whose components are further and further apart. AITKEN has also found that a larger proportion of bright stars are double than is the case for fainter stars. With an infinity of time for the evolutionary processes involved, it seems difficult to explain the greater scarcity of wide pairs. But this is a fact which presumably has great significance. My radial velocity studies of the stars seem to indicate that the stars of different magnitudes are mixed much more thoroughly in space than has heretofore been supposed. It seems, therefore, quite probable, in the absence of accurate parallax data, that the fainter double-star systems are actually closer to us, on the average, than the earlier investigations have led us to believe. It seems reasonable also that large parent nebulæ should divide into two components more freely than small nebulæ do.

Tables III and IV do not include the *Cepheid-Geminid* variables, for the reason that these mysterious systems seem to be in a class by themselves, so far as our present knowledge goes.

TABLE VIII.—CEPHEID-GEMINID VARIABLES.

No. of stars.	Period in days.	No. of stars.	Period in days.	No. of stars.	Period in days.
7	0-1	1	8-9	1	27
0	1-2	3	9-10	1	35
1	2-3	1	10	1	38
5	3-4	2	12	1	39
5	4-5	1	14	1	41
5	5-6	1	16	—	
5	6-7	2	17	53	
8	7-8	1	20		

[1] *Lick Observatory Bulletin*, 6, 1, 1910.

TABLE VIII.—CEPHEID-GEMINID VARIABLES—*Continued.*

11 orbits computed.

$P^{11} = 7^d.3$

$e_{11} = 0.31$

Spectrum	O-B	A	F	G-K5	M	Unknown
No.	0	1	14	26	0	12
Average period		$0^d.6$	$8^d.2$	$11^d.4$		$7^d.9$

Table VIII refers to fifty-three variables of this class, with periods distributed as in the second column. To seven are assigned periods less than one day. I suspect that some of these extremely short period variables may, in fact, later be assigned to the cluster type of variables; or it is not impossible that the cluster-type variables are entitled to classification with the *Cepheid* variables. None of the many hundreds of cluster-type variables discovered by Harvard College Observatory have yet been submitted to radial velocity measurements, owing to their faintness. There are twenty-eight of the *Cepheid-Geminid* variables with periods between two and eight days. Spectrographic orbits have been computed for eleven members of this class, with average periods of 7.3 days and eccentricity 0.31. The numbers and periods corresponding to the different spectral types are quoted in the table. There are none of the Q, O, B, or M type, so far as known. There is only one A type; and there are thirty-nine advanced F type and G type. The length of period seems to increase slowly with the spectral type, but the relationship is not strongly marked.

TABLE IX.—CEPHEID-GEMINID VARIABLES.

H. R.	Star	Types	Period (d)	e	$a \sin i$	$\frac{m^3_1 \sin^3 i}{(m+m_1)^2}$	$\text{Min}_v\text{-Max}_1$ (d)	$\text{Max}_v\text{-Min}$ (d)
2332	RT *Aurigæ*	G	3.73	0.37	856,500	0.0018	+ 0.2	+ 0.4
7518	SU *Cygni*	F5	3.84	0.21 ±	1,350,000 ±	0.0058 ±	+ 0.2 ±	+ 0.0 ±
7988	T *Vulpec.*	F	4.44	0.43	969,180	0.0018	+ 0.3	+ 0.1
8571	δ *Cephei*	G	5.37	0.36	1,371,000	0.0037		
6863	Y *Sagittarii*	G	5.77	0.16	1,485,000	0.0040	+ 0.78	+ 0.1 ±
6616	X *Sagittarii*	F8	7.01	0.40	1,334,000	0.0016	— 0.2 ±	— 1.3 ±
7402	U *Aquilæ*	G	7.02				— 0.5	
7570	η *Aquilæ*	G	7.18	0.49	1,773,000	0.0043	0.0 ±	— 0.6
6742	W *Sagittarii*	F5	7.60	0.32	1,930,000	0.0050	— 0.1	+ 0.2
7609	S *Sagittæ*	G	8.38	0.35 ±	2,000,000 ±	0.0049 ±	— 0.2 ±	+ 0.4 ±
7107	κ *Pavonis*	F5	9.09					
2650	ζ *Gemin.*	G	10.15	0.22	1,797,800	0.0023	— 0.2	— 0.3
7932	X *Cygni*	F5p	16.39					
6661	Y *Ophiuchi*	G	17.12	0.10	1,999,000	0.0011	— 1.3	+ 0.5 ±
2310	T *Monocer.*	G	27.01					
3884	l *Carinæ*	G	35.53				— 2½ ±	

Table IX contains the principal orbital elements, so far as known, for sixteen stars of this class, arranged in the order of their periods. A most peculiar discovery concerning these systems, as described in the last two columns of the table, was made by ALBRECHT several years ago: each star has its maximum brightness at or near the time of most rapid approach *toward the observer,* and its minimum at or near the time when receding most rapidly *from the observer.* Orbits of enough stars in this class have been investigated to guarantee, beyond reasonable doubt, the conclusion that the time of maximum in each of the systems is a function of the observer's position in space. Many theories to account for this strange phenomenon have been advanced and discussed, only to be found wholly or largely unsatisfactory.

Several additional conclusions can be drawn from the data. The ratios in the second column from the last indicate clearly that the masses of the companion stars are very small in proportion to the masses of their primaries. The column "$a \sin i$" declares that the primaries revolve in orbits whose dimensions may be described as minute.

It is reasonably certain that all *Cepheid-Geminid* variables, as well as *Algol* variables, are spectroscopic binary systems. The future will probably establish the fact that the cluster variables are binaries.

The importance of spectroscopic binary investigations, in their bearing upon questions of the origin and development of multiple star systems, can scarcely be overestimated.

NOTES ON SOLAR MAGNETIC FIELDS AND RELATED PHENOMENA.

By GEORGE E. HALE.

CLASSIFICATION OF SUN-SPOT LINES.

A study of the Zeeman effect in the spectra of sun-spots has made it necessary to formulate a system of classification of the numerous types of lines observed under various conditions. Before the present work was undertaken, spot spectra were known to include band lines, belonging to the flutings of such compounds as titanium oxide, magnesium hydride,

and calcium hydride (or possibly magnesium and calcium in the presence of hydrogen); strengthened lines, many of which are widened; weakened lines; lines which are completely obliterated; reversed lines; thinned lines, and winged lines. The presence of broad wings like those of the D lines may or may not be caused by the magnetic field, but the evidence thus far obtained is opposed to this explanation. The effects which have been clearly proved to be due to the field include the widening of many lines, some of which are of uniform intensity, while others are strengthened or weakened at the center; the separation of a few lines into quadruplets and of many others into doublets, which have been shown by laboratory experiments to be quadruplets, the outer members of each pair being too close for resolution in the comparatively weak field of the sun-spot; and the formation of triplets. In the triplets a great variety of phenomena are observed. In some cases the central line is very weak, while in others it is twice as strong as the side components. Again, all three components of a triplet may appear sharp, while under other conditions the central line of the same triplet may be sharp and the side components broad and diffuse. In the same spot spectrum triplets showing a uniform separation across the umbra may be accompanied by others in which the side components converge. Again, a line may be triple on one side of a spot and double on the other, as the result of a gradual change in the intensity of the central component.

When a Nicol is used the variety of phenomena is considerably increased. For example, it is possible, under certain conditions, using a Nicol without rhomb or quarter-wave plate, to cut off one of the side members of a triplet, leaving the other side member of normal intensity. Such an effect results from the elliptic polarization produced by the mirrors of the tower telescope. Without such polarization the side components would be affected alike by the Nicol, unless used with a rhomb or quarter-wave plate, when either could be extinguished at will. Another interesting phenomenon has also been observed with the Nicol. If it is set in a certain position, the central line of a triplet may be strong on one side of the umbra and weak on the other. Rotation of the Nicol through 90° reverses the relative intensities.

On account of the comparative weakness of the field in spots, many triplets and quadruplets are not completely resolved, but merely widened. By the use of a Nicol the central components of such lines can be reduced in intensity or cut out completely. Final decision whether a given line is a triplet or a quadruplet must be based upon comparison with laboratory results, since the inner components of some quadruplets are so close together as to cause these lines to appear like triplets, unless the magnetic field is very strong.

A tentative system for briefly designating all of these different types of lines has been adopted, for use in tables of wave-lengths and other places where lengthy descriptions cannot be employed.

DIRECTION OF THE AXIS OF THE ELECTRIC VORTEX.

In a normal triplet, observed at right angles to the lines of force in the laboratory, the central line is twice as intense as the side components. When observed parallel to the lines of force, the central line disappears completely. Thus the ratio of the intensities gives a means of determining the angle between the lines of force and the line of sight. Such a triplet as λ 6302.71 (iron) appears under widely different aspects in the spectra of sun-spots. In some cases the central line is weaker than the side components, while in others it is twice as intense. Such differences of intensity, however, are not due solely to differences in the inclination of the axis of the electric vortex to the line of sight. To determine the true relative intensities of the lines we must take into account the polarization resulting from reflection on the silvered mirrors of the tower telescope, the polarizing effect of the grating of the spectrograph, and the rotation of the plane of polarization produced by the spot vapors, which is discussed below. In order to interpret the photographs we must therefore measure the polarization phenomena due to the tower telescope, and for this purpose a special instrument has been constructed. In this instrument a monochromatic light source can be set at the declination and hour angle of the sun recorded at the time of observation. The light from the source is plane or circularly polarized with the aid of a Nicol, used with or without a quarter-wave plate. The parallel beam then falls on

the mirror of a very small cœlostat, from which it is reflected to a second mirror, both being set in precisely the same relative positions that the mirrors of the tower telescope occupied at the time of observation. The polarization phenomena thus produced are measured with the aid of a Nicol, used alone or in conjunction with a quarter-wave plate. In this way the change of intensity of any type of line caused by the tower telescope can be determined.[1]

As ZEEMAN has shown, rotation of the spectrograph is in itself sufficient to reverse the relative intensities of the central and side lines of a triplet. Hence the position angle of the spectrograph at the time of observation must be known, in order to determine the true relative intensities of the lines. But even this is not sufficient, because of the change in intensity of different parts of the central line of a triplet sometimes observed when the Nicol is rotated. However, by finding the two positions of the Nicol giving the *maximum* intensity of the central and the side lines of a triplet at the center of the umbra, the inclination of the lines of force to the line of sight can be determined.

ROTATION OF THE PLANE OF POLARIZATION OF LIGHT EMITTED IN SUN-SPOTS.

FARADAY discovered in 1846 that when plane polarized light is passed in the direction of the lines of force through a block of heavy glass in a magnetic field, its plane of polarization is rotated. It was found later that other substances in the magnetic field, including metallic vapors, produce the same effect. In a sun-spot the central line of a triplet is a source of plane polarized light. If this passes toward the observer along the lines of force of the magnetic field, its plane of polarization must be rotated. Hence the degree of absorption at higher levels in the spot vapors, which determines the total intensity of the line, must be affected. In this way we may probably account for the phenomena observed in certain triplets. As already remarked, when the Nicol is placed in a certain position, the central line of a triplet is found in some spots to be strong on one side of the umbra and weak on the other. When the Nicol is turned through an angle of 90°,

[1] In certain cases the polarization phenomena produced by the mirrors actually employed with the tower telescope are measured directly.

the line becomes strong on the side of the umbra where it was previously weak and weak on the side where it was previously strong. If the effect is due to the rotation of the plane of polarization, we should expect a similar phenomenon to appear in the case of the side members of the triplet. In general, the light does not come exactly along the lines of force, but makes a considerable angle with them. Under these circumstances the side members of triplets are elliptically polarized. The circularly polarized component of this light is not visibly affected by transmission through the vapor. The plane of polarization of the plane polarized component must, however, be rotated. As the plane of polarization of the side members is at right angles to that of the central line, the effect ought to be opposite in sign to that given by it. Moreover, it should be less in degree, since the circularly polarized component of the light will remain of unchanged intensity. Just such an effect is actually observed in sun-spots. There can therefore be little doubt that we are observing the phenomenon of the rotation of the plane of polarization in the spot vapors.

On this hypothesis the difference in intensity of the central line on opposite sides of the spot must be due to a difference in the thickness or density of the vapor, or the strength of the field, in the two positions. However, another effect may enter here to complicate the question. It has already been mentioned that in some cases triplets are observed, without a Nicol, in which the central line is strong on one side of a spot and weak on the other. The polarizing effect of the grating of the spectrograph may be sufficient to give rise to such a phenomenon, even without a Nicol, in accordance with the hypothesis outlined above. Another cause might be a difference in the direction of the field on opposite sides of the spot. As we have other reasons for believing that such a difference in the direction of the field must sometimes exist, it is evident that a careful series of observations must be carried out in order to separate the two classes of phenomena. As already remarked, however, such complicating effects need not prevent us from determining the angle between the lines of force and the line of sight, provided that the polarizing effects of the tower telescope and spectrograph be allowed for,

and the maximum intensities of the central and side lines of the triplet be determined by turning the Nicol to the proper positions.

STRENGTH OF THE FIELD IN DIFFERENT PARTS OF A SPOT.

In general, the separation of the components of a triplet is greatest near the center of the umbra, and decreases gradually until the outer boundary of the penumbra is reached, where the line is of about its normal width. However, certain spot lines are widened beyond the limits of the penumbra and even at points some distance away. To determine the presence of very weak fields, the following device serves to good advantage. Using a Nicol and rhomb, set so as to transmit one of the outer components of a triplet, a photograph of the spectrum is made. During the exposure a small metal plate, containing a series of holes 1^{mm} in diameter and 1^{mm} apart, is mounted just above the slit of the spectrograph. After the exposure the plate is moved through a short distance, so as to bring another set of holes into position above the slit, in order to uncover those regions which were covered during the first exposure. The Nicol is then turned through 90°, so as to transmit the opposite component of the triplet, and a second exposure is made. As the alternate strips of spectra on the plate then show the opposite components of the triplet, even a very weak field produces a sufficient displacement of the line to show itself. A better arrangement, which I am about to employ, will be afforded by the use with the Nicol of narrow strips of mica (quarter-wave plates), mounted so that the principal planes of adjoining strips are at right angles to one another. A single exposure will then give all of the spectra simultaneously.

In some spots the maximum strength of the field is not found at the center of the umbra. Furthermore, as already mentioned, we sometimes find in the same spectrum triplets or quadruplets the components of which are parallel in some cases and convergent in others. We must be dealing in the latter instance with phenomena produced at different levels.

STRENGTH OF THE FIELD AT DIFFERENT LEVELS.

In my paper "On the Probable Existence of a Magnetic Field in Sun-Spots,"[1] I showed that while four lines of iron indicated nearly equal field-strengths in a spot, lines of titanium and chromium gave widely different values. These were attributed to differences in the mean level represented by the absorption of these lines. This hypothesis has received support from various directions. It is found, for example, that while substances like iron and other elements which lie at a comparatively low level in the solar atmosphere indicate a field strength as great as 4,500 units, the high-level *b* lines of magnesium and the D lines of sodium give a very weak field, while no field can be detected with the hydrogen lines. Furthermore, as mentioned above, parallel and convergent lines occur on the same plate. There is no great difficulty in assuming that the rate of change in the strength of the field from one side of the umbra to the other may be different at different levels, whereas we could not easily explain such an effect if vapors lying at the same level were supposed to produce it.

STRENGTH OF THE FIELD AT DIFFERENT PERIODS IN THE LIFE OF A SPOT.

The earlier observations indicated that large spots gave stronger fields than small ones, and this suggested that differences in the strength of the field might be expected at different periods in the life of a spot. Such changes have been found. In connection with this investigation the life history of each spot is carefully studied, especial attention being directed to such phenomena as the area of the spot, the type of the spot, the area of the calcium flocculi, the visibility and curvature of the stream lines in the $H\alpha$ vortices, the number and activity of eruptive phenomena, etc.

METHOD OF MAPPING THE MAGNETIC FIELDS OF THE SUN.

One method of detecting the existence of weak magnetic fields outside of spots has already been described. Another, which serves especially for the study of the stronger fields in different parts of the umbra and penumbra, and in the several

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 30; *Astrophysical Journal*, **28**, 320, 1908.

spots of a group, may now be mentioned. A large solar image is necessary. The spectrograph is provided with a multiple slit, so constructed as to permit the spectra given by a series of parallel slits about 2^{mm} apart to be photographed simultaneously on the same plate. It is not considered sufficient to record only a single line: several lines are needed in order to give the field-strength at different levels. One of the best regions that can be chosen is that lying on both sides of the quadruplet λ 6301.72 and the triplet λ 6302.71, as this contains many interesting lines. A rhomb or quarter-wave plate is used with the Nicol, which is set so as to transmit one of the outer components of a triplet. Suppose the slits to be set across a spot group, and consider the appearance of the lines in an actual case (September 25, 1909) where one of the slits crossed the umbra and penumbra of a large spot and passed through a small spot lying just within the edge of the same penumbra. One side member of such a triplet as λ 6302.71 was completely cut off. The other appeared as a curved line, departing toward the violet from its normal position near the edge of the penumbra, reaching a maximum displacement in the umbra of the spot, and then curving gradually back as it approached the other edge of the penumbra. Just before reaching the small spot it returned sharply to its normal position, then continued across to the opposite (red) side of the line, returning to the normal position at the point where the slit passed beyond the small spot. We have here a case where the polarities of the large umbra and its enveloping penumbra were of one sign, while that of the small spot lying within the same penumbra was of the opposite sign. Three other small spots within the same penumbra were also opposite in polarity to the large spot. In other cases all of the spots in the same group have been found to be of the same polarity. It is evident that the photographs permit the strength of the field, as well as the polarity, to be determined at many points within a spot group. In some cases it may be advantageous to use a multiple mica quarter-wave plate, made up of narrow strips, as described above. To complete the record, a device may be used for photographing a series of parallel images of any desired line on a plate, at the same distance apart as the slits of the spectrograph. Superposed upon such a photograph, an *Hα* image of

the spot, reproduced from a spectroheliograph plate, will serve to show the direction of curvature of the stream lines of the vortices in all parts of the field.

PAIRS OF SPOTS OF OPPOSITE POLARITY.

In a previous paper[1] I have briefly alluded to a pair of spots, of opposite polarity, which appeared to be physically related. The principal reasons favoring this connection were the structure of the vortices on the $H\alpha$ photographs, the fact that the axes of the vortices were considerably inclined to solar radii passing through the spots, and the eruptions found by FOX and ABETTI to extend completely across from one spot to another.[2] Furthermore, the rapid decrease upward in the strength of the field in spots pointed to the view that the electric vortex which produces the field must lie at a low level, presumably within the photosphere. As EMDEN'S solar theory assumes the existence of such vortices, it was remarked that the evidence then available seemed to favor this theory.

Since that time various other cases of apparently related spots, of opposite polarity, have been observed. Some of these are very remarkable, the appearance of the $H\alpha$ photographs being such as to resemble closely the lines of force of a bar magnet, the opposite ends of which are supposed to coincide in position with the two spots. The relationship between the curvature of the $H\alpha$ flocculi and the observed polarities is so close that the relative polarities of two neighboring spots may almost always be correctly inferred by an examination of the flocculi on any $H\alpha$ plate.

NATURE OF THE HYDROGEN FLOCCULI.

On June 17, 1909, I discussed before the Royal Society various hypotheses which have been advanced to account for the hydrogen flocculi. When preparing my paper for publication, I confined myself to a brief consideration of the hypotheses advanced by LOCKYER, DESLANDRES, JULIUS, and myself, arriving at the conclusion that the dark hydrogen flocculi are, in the main, absorption phenomena.[3] The problem

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[1] "Sur les Champs Magnétiques des Taches Solaires," *Journal de Physique*, July, 1909.

[2] *Astrophysical Journal*, **29**, 40, 1909.

[3] "On the Nature of the Hydrogen Flocculi and Their Structure at Different Levels in the Solar Atmosphere."—*Proceedings of the Royal Society*, A. **83**, 177, 1909.

of explaining the changes in the structure of the flocculi, as shown on photographs exhibited at the meeting, was reserved for subsequent discussion, when the reduction of the photographs could be completed. Although this work is still in progress, it seems desirable at the present time to refer to its bearing on BRESTER's aurora hypothesis of the hydrogen flocculi.[1] In his paper it was first suggested that the phenomena shown on $H\alpha$ plates are not hydrodynamical, but correspond with the auroras of the earth's atmosphere, as explained by BIRKELAND and others. In BRESTER's opinion, electrically charged particles, supposed to be emitted by radio-active substances in sun-spots, pass out through the solar atmosphere, where they produce luminescence. According to BIRKELAND's theory, the form of the aurora is determined by the earth's magnetic field. The same hypothesis, applied to the Sun, requires that the configuration of the flocculi be governed by the magnetic field in spots. DESLANDRES has recently advocated a similar view.[2]

Let us consider the conditions which may affect the intensity of the flocculi. Bright eruptive flocculi, which are usually of short life and change rapidly in form, are shown in spectroheliograms made with H_2 and the center of $H\alpha$, but ordinarily they do not appear when the camera slit is set on H_1 or on the edge of $H\alpha$. If these were eruptions of intensely heated vapor, we should expect their brightness at the photospheric level to be at least as great as at higher altitudes, where the effect of expansion would naturally tend to cool the vapor. It thus seems probable that the exceptional brightness of these eruptive regions is due to some effect experienced by the vapor after it has passed above the H_1 level. A separation of the positive and negative ions in the moving mass of gas might result in electric discharges similar to lightning. If the discharges could be assumed to persist for a sufficient time, the brightness of the eruptive vapor might perhaps be accounted for in this way. Or electrons, emitted in great numbers under the low pressure of the region into which the vapor has suddenly been transported, might contribute materially to the luminescence of the

[1] Amsterdam Academy of Sciences, January 30, 1909.
[2] *Comptes Rendus*, January 10, 1910.

mass. As terrestrial magnetic storms are usually found to be associated with sun-spot groups in which eruptions are numerous, it seems probable that such eruptions may contribute largely to the stream of electrons which pass from the Sun's atmosphere to that of the Earth. It should be noted that these bright eruptive regions exhibit little (if any) of the curved structure which causes the dark $H\alpha$ flocculi to resemble vortices.

These dark flocculi, as explained in the paper mentioned above, are probably due in the main to the absorption of comparatively cool hydrogen. Nevertheless, their changes are sometimes such as to suggest the possibility that the absorption may be partially offset by the luminescence arising from streams of electrons.[1] On June 3, 1908, a large dark hydrogen flocculus was photographed by Dr. St. John just as it was being sucked into a spot. I cannot account for this phenomenon except as representing an actual flow of absorbing hydrogen toward the spot. The fact that the outline of the flocculus was still faintly visible on the last photograph of the series does not seem to me to oppose this view, since only the gas at a comparatively high level may have been swept into the vortex. In most other cases, however, the curved hydrogen flocculi near spots, which resemble the lines of force in a magnetic field, do not show such evidences of actual motion. On the contrary, their intensity changes are sometimes periodic in character, the dark flocculi appearing strong in some photographs, weak in later ones, and strong again in still later images. I have studied such phenomena on long series of photographs made at intervals of about one minute, and have been forced to the conclusion that the hydrogen of the dark flocculi must undergo more or less periodic changes, such as might result from an intermittent bombardment of electrons.

In considering this question, we must not overlook other possible causes of such changes, such as differences in the volume, pressure, temperature and level of the gas. Certain phenomena are most easily explained as eruptive prominences, seen in projection against the Sun. A notable case of this kind is illustrated by a series of photographs made with $H\alpha$

[1] Electric discharges or other causes of luminescence may increase the brightness of certain regions, but I fail to see how the formation of flocculi much darker than the general background can be accounted for in this way.

on September 10, 1908. At 6^h 33^m a small, brilliant flocculus could be seen on the edge of a sun-spot: Its brightness and area increased rapidly, reaching a maximum about 6^h 39^m. Meanwhile, a dark flocculus appeared on the outer edge (away from the spot) of the bright area. At 6^h 43^m the area of the bright flocculus was less than half as great as at 6^h 39^m, but the dark flocculus extended away from the spot as a long streamer, apparently of cooler gas falling back toward the Sun. Eight minutes later it attained its greatest length, and was very dark at its outer end. At 7^h 0^m no trace of the bright flocculus remained, and the dark flocculus was shorter and less intense.

SPECTROHELIOGRAMS SHOWING ASCENDING AND DESCENDING FLOCCULI.

Photographs made by Mr. ELLERMAN and myself with the 30-foot Littrow spectroheliograph of the 60-foot tower telescope seem to afford a useful means of distinguishing between ascending and descending gases in eruptive phenomena. The mirror ordinarily used behind the 60° prism of the spectroheliograph is replaced by two mirrors, so adjusted as to give two parallel spectra in the focal plane of the camera objective. Thus two images of the $H\alpha$ line are obtained with light from a single collimator slit. By the use of two camera slits, one set on the red edge of $H\alpha$ in one spectrum, the other on the violet edge of the same line in the other spectrum, two photographs of the flocculi can be taken simultaneously.

In some eruptions, the bright reversal of $H\alpha$ seems to be confined to the central part of the line, so that such phenomena are not shown when the camera slit is set near the edge. In other cases, however, $H\alpha$ is brightened across its entire width. A remarkable eruption photographed on May 12, 1909, was of the latter class. The image obtained with the violet edge of the line shows extensive bright flocculi, lying between two spots. These also appear, with some differences in form, in the image given by the red edge. The latter shows, in addition, a remarkable group of dark flocculi, which appear as a series of nearly parallel straight lines in the space between the spots, and as curved lines, resembling lines of force, at greater distances from the line joining the spots. If the dark flocculi

shown only by light from the red edge of the line actually represent descending masses of cooler gas, the method is likely to prove of service in further studies of such phenomena. The dispersion used was that of a single 60° prism of ethyl cinnamate, twice traversed by the light, employed with a combined collimating and camera objective of 30 feet focal length. With higher dispersion it should be possible to photograph separately ascending and descending gases which do not differ greatly in radial velocity.[1]

NATURE OF THE VORTEX STRUCTURE

The spiral configurations associated with sun-spots, described in my paper "Solar Vortices,"[2] were there called "vortices" for two principal reasons: their forms closely resemble vortices, and the phenomenon photographed by Dr. St. John on June 3, 1908, appeared to represent a mass of hydrogen in the act of being sucked into a spot. On the hypothesis that such vortices in the solar atmosphere might give rise to magnetic fields in sun-spots, the Zeeman effect was sought and immediately found. Right- and left-handed vortices were then shown to be of opposite polarity. As the only known means of producing a solar magnetic field, similar to that observed in spots, is the rapid revolution of electrically charged particles, we may safely conclude that sun-spots are vortices.

For reasons already mentioned, I came to the conclusion that the vortex which produces the field must lie within the photosphere. The hydrogen lines in spot spectra show no indication of the Zeeman effect and hence the field is very weak

[1] A spectroheliograph of this kind might give interesting results if used with a Nicol and quarter-wave plate or Fresnel rhomb. If one camera slit were set on the red component of a Zeeman quadruplet, and the other on the violet component, two photographs secured simultaneously should record separately regions having magnetic fields of opposite polarity. On account of the strong general absorption, the method is not likely to apply well to spots, but it may be useful in detecting weak fields in other parts of the Sun. For this purpose high dispersion is required, and the camera slits must be set only a short distance to the red and violet of the center of the line. A line which is narrow in the solar spectrum, and widely separated by a magnetic field, should be chosen for the work. Differences in the separation of the components, due to fields of different strength, should not be an insuperable obstacle. In some cases it may be advantageous to photograph regions in which a line is merely widened, without complete separation. For this purpose an ordinary spectroheliograph, with single camera slit, may be employed, with or without a Nicol and quarter-wave plate.

[2] *Contributions from the Mount Wilson Solar Observatory*, No. 26; *Astrophysical Journal*, **28**, September, 1908.

at high levels. It does not follow, however, that the revolution of electrically charged particles at the level represented by *Ha* produces no magnetic field. The field may be too weak to give an appreciable Zeeman effect, or it may be opposite in sign to the field originating at a lower level, which would thus partially or wholly counteract it. The relative proportion of positive and negative electrons probably differs at different levels in the solar atmosphere. A preponderance of positive electrons at one level, and of negative electrons at another, if whirled in the same vortex would produce fields of opposite sign.

EVERSHED's recent spectroheliographic results indicate that there is an outward flow, parallel to the photosphere, from the center of sun-spots at the iron level, and an inward flow at the H_3 level. Although the flow was at first considered to be radial, a tangential component has since been detected, so that the observed phenomena, at the H_3 level, are brought into harmony with those shown in spectroheliograph images of the *Ha* flocculi.

In my paper on "Solar Vortices" I called attention to the exact correspondence between the analytical relations developed in the theory of vortices and the theory of electro-magnetism. This identity shows why hydrodynamical phenomena sometimes cannot be distinguished in appearance from the corresponding electro-magnetic phenomena. BJERKNES has given many interesting illustrations of such agreement in his work "Die Kraftfelder."

In spite of the phenomenon of June 3, 1908, and the support afforded by EVERSHED's recent investigations, the hydrodynamical theory cannot be said to be superior in all points to the electro-magnetic theory of the hydrogen flocculi. Moving electrons would undoubtedly be deflected by the magnetic fields in sun-spots, and the apparent lines of force which frequently unite spots of opposite polarity seem highly suggestive. However, it should be possible to find criteria which will enable us to decide whether these lines are produced by the magnetic fields themselves, or are of hydrodynamical origin.

We may first recall that the apparent vortex structure is best shown on spectroheliograms made with the camera slit set at some point between the center and edge of the *Ha* line.

Such structure is less clearly shown with the more refrangible hydrogen lines, which represent a lower level in the solar atmosphere.[1] However, $H\delta$ often shows the apparent lines of force between two spots, though it fails to bring out some of the most remarkable structure photographed with $H\alpha$. Even the H_2 flocculi have a similar structure, which is easily recognized when we know that spots of different polarities often occur in the same group. We may even detect evidences of the operation of the same force in the structure of the H_1 flocculi and the faculæ. The striking resemblance between the $H\alpha$ flocculi and the penumbral filaments of LANGLEY'S exquisite drawings, to which I have alluded in previous papers, apparently completes the connection between the upper and lower levels. Opposite directions of curvature of the penumbral filaments in different parts of the spot group should in this case mean opposite polarities. This is being tested, and a comparative study of penumbral and $H\alpha$ structure is also in progress.

In a recent paper DESLANDRES suggests that the failure of the H_2 photographs to show the apparent lines of force is due to the greater mass of the calcium ion, which would be less deflected by the field than the hydrogen ion.[2] We have seen, however, that apparent lines of force having about the same curvature as the dark $H\alpha$ flocculi are frequently shown by H_2 between spots of opposite polarity, though this line fails to give most of the finer details of the $H\alpha$ structure. The difference may be due in large part to the greater effect of convection current at the H_2 level. The apparent lines of force, or vortex structures, are best shown in the higher atmosphere, where the slowly descending gases are less affected by other influences. The very strong field at low levels should deflect moving ions much more than the very weak field at the $H\alpha$ level, but possibly convection may conceal such an effect.

Another mode of attacking the question avoids the convection difficulty. On the aurora hypothesis it is only reasonable to suppose that large spots, having strong magnetic fields, should be capable of defining the structure of the hydrogen flocculi at a much greater distance than small spots, having weak fields. Nevertheless, we find in practice that some groups

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[1] *Proceedings of the Royal Society*, A. **83**, 177, 1909.

[2] *Loc cit.*

of very small spots, like that of April 30, 1908, are surrounded by a great cyclonic structure in the hydrogen flocculi, extending over a distance equal to about one third of the Sun's diameter, while it is frequently true that large spots, with strong magnetic fields, seem to influence the form of the flocculi over a very much smaller area. Thus it can hardly be said that such evidence is favorable to the electro-magnetic explanation, particularly when it is remembered that beautiful cases of apparent lines of force or vortex structure, covering great areas, are frequently shown on $H\alpha$ photographs in regions where no spot is present.

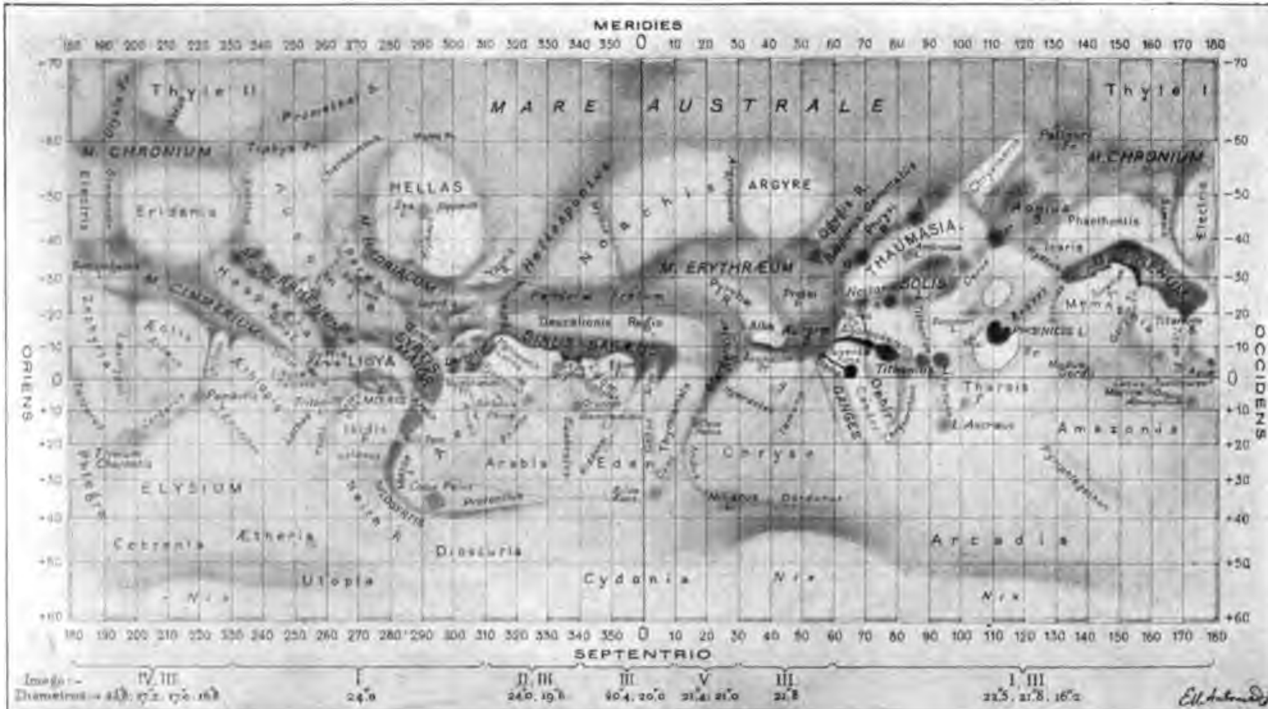
The questions raised in these notes will be discussed more fully in a paper containing the quantitative results of the present investigation, which will soon be published. A single suggestion may, however, be added here. If the apparent lines of force uniting two spots of opposite polarity are of hydrodynamical origin, they suggest that one spot should be regarded as a source and the other as a sink. As EVERSHED's published results all indicate an inward flow at the H_3 level, the existing data seem to be opposed in this case to the hydrodynamical explanation.

A REVIEW OF THE RECENT OBSERVATIONS OF *MARS*.[1]

BY R. G. AITKEN.

It is my purpose this evening to give you a short account of the recent observations of *Mars*, and of the general conclusions that I think may fairly be drawn from these observations. As a man's opinions are necessarily influenced in a greater or less degree by his experience and training, it may be well to premise that I speak from the point of view, not of the expert areographer, but of the interested student, who has familiarized himself with the literature of the subject and who has also had many opportunities during the past sixteen years to study the planet directly, under favorable observing condi-

[1] This is an abstract of an address given before the Society at its annual meeting on March 26, 1910. Lantern slides of drawings and photographs of *Mars* made during the last three opposition periods were exhibited to illustrate the address.



GENERAL MAP OF THE PLANET MARS.
From observations made at Meudon in 1909 by E. M. ANTONIADI.

tions, with refracting telescopes varying in aperture from 3½ inches to 36 inches.

. . . .

We may say, then, that in recent years observations of *Mars* have had for their main object the settlement of two questions —(1) What is the nature of the surface detail, and, particularly, of that portion known as the "canals"? (2) Is it possible by direct observation to establish indisputably the fact that water vapor exists in the Martian atmosphere? In connection with the former a practical question of considerable interest has been raised,—namely, the size of telescope best adapted to the study of planetary detail.

What light have the observations during the recent opposition of the planet thrown upon these questions?

No complete account of Mr. LOWELL'S work during the past year has as yet been published, but from some short bulletins and notes from his pen it is clear that his observations have only confirmed him in the views that he has previously expressed. For example, he has recently announced the discovery of two canals—new not only in the sense that they had not previously been seen by terrestrial observers, but also new, in his opinion, to *Mars* itself. Speaking of these canals, he says: "In form they are like all the other canals—narrow, regular lines of even width throughout, running with geometric precision from definite points to another point where an oasis is located. This oasis resembles all the other oases—a small, round, dark spot. They partake, therefore, of all the peculiar features of the canal system—features which I have elsewhere shown make it impossible of natural creation,—that is, of being the result of any purely physical forces of which we have cognizance. On the other hand, the system exactly resembles what life there would evolve under the conditions we know to exist." [1]

Mr. LOWELL thus gives a clear statement of one answer to our first question. In his view, the canals are the visible evidence of a vast irrigation system developed by Martian engineers to husband and distribute economically the scanty supply of water that exists upon the planet.

[1] *Nature*, **82**, 489, 1910.

The great majority of observers during the past opposition, however, take direct issue with Mr. LOWELL on this point; for almost without exception their testimony is that they have been unable to detect any evidence of the existence of this geometrical network of canals. Surface detail in abundance they have seen and drawn in their sketches, including many canals. But the latter are, in general, not of uniform width and shading; they are not perfectly straight; they do not follow great circle arcs. In general, too, they are not so narrow as Mr. LOWELL'S canals. In a word, they have a less artificial and a more natural appearance. Thus, the well-known English observer, Mr. A. STANLEY WILLIAMS, uses the word "irregularity" to characterize the dominant impression received by him in his study of the planet's surface. There were plenty of so-called canals, "but not one of them could be described as a geometrical, narrow, straight line of uniform width. All were obviously more or less irregular or complex." M. COMAS SOLA and M. ANTONIADI, who, like Mr. WILLIAMS, are observers of recognized ability and who have, like him, studied *Mars* for years, are even more emphatic in their statements. Indeed, they do not hesitate to say that the geometrical canal system is a pure illusion.

M. R. JONCKHEERE, on the other hand, enthusiastically supports Mr. LOWELL'S observations and, in fact, surpasses them. For, with a 14-inch telescope, he sees all of the older canals, verifies every one of the four hundred discovered at Flagstaff, and *adds twenty-three new ones!*

I have mentioned only a few observers and only a few typical statements of results. The time limits set me do not permit me to go into great detail. But I think it will be clear to you from what I have said that our first question is not yet conclusively answered.

It should be noted that Mr. WILLIAMS'S telescope is a reflector with a 6½-inch mirror; that M. COMAS SOLA employed a refractor of 15 inches aperture, while M. ANTONIADI enjoyed the privilege of using the 33½-inch Meudon refractor, the largest one in Europe. Mr. LOWELL, as is well known, uses a 24-inch refractor, which, if I am not mistaken, he sometimes, or frequently, stops down to a smaller aperture. These details have a significant bearing upon the practical question

of the size of telescope best adapted to study planetary markings, for they show that up to the limit of 24 inches aperture, at least, the visibility of the geometrical canal system is not a function of the aperture of the telescope. It is quite true that these particular markings have not been seen with the great refractors of the world, and persistent efforts have been made in recent years to discredit the large telescopes on this account. So far as I am aware, observers who have had the opportunity to use these powerful instruments under reasonably good observing conditions, have never participated in these efforts. On the contrary, I think I may say that without exception they would endorse the statement made by Professor BARNARD as long ago as 1896, in which he gives it as his experience that in the study of planetary markings the large telescope is always to be preferred to the small one when the seeing is good. Also, that, with the same proviso, nothing is gained, but something lost, when the aperture is cut down by diaphragms.

As the result of his recent experience with the 33½-inch Meudon refractor, M. ANTONIADI enthusiastically confirms BARNARD'S views. Professor HALE, who has been examining *Mars* both visually and photographically with the 60-inch reflecting telescope at Mount Wilson, also supports these views heartily. All three of these observers point out that while they have been unable to see a trace of the geometrical network, they have seen a great amount of detail, much of it far more delicate and fine than the "canals."

It is of course true that the almost constant disturbances in the Earth's atmosphere make it impossible to realize the full power of a large telescope on many nights when a smaller instrument can be used to advantage, and that "good seeing" is indispensable for the best work with a telescope of any aperture. It is beyond question that fine details can be seen with a small telescope under good atmospheric conditions that would be missed with a larger one when the seeing is bad. Every experienced observer is aware of this, and Mr. LOWELL and M. ANTONIADI are in entire accord in stating that good views of the surface detail on *Mars* are only to be enjoyed when the seeing is good.

The question may then be asked, Can it be due to differences in the seeing that one observer sees the geometrical net-

work of the canals while another does not? The records of the past year's work on *Mars* make it very difficult to believe that this is the explanation. There may be more nights with good seeing at one station than at another, but certainly there were some good nights last year at all the stations from which *Mars* was observed. M. ANTONIADI, for example, expressly states that the seeing at Meudon was bad on many nights and excellent on but few, but it was when the seeing was best that he saw the finest detail, and was at the same time most certain of the absence of the geometrical canal system. Mr. LOWELL praises the atmospheric conditions at Flagstaff in the highest terms, and he sees the canals; it is admitted by astronomers generally that the seeing at Mount Hamilton is good, and we do not see the canals. I have not, personally, had the privilege of comparing the seeing at these two sites, but I have discussed the subject with at least four astronomers —two from each observatory—who have looked through the telescopes at both places, and from all I gain the very definite impression that our standard of gauging the seeing is higher than the one in use at Flagstaff. That is, seeing that is there rated at 3 (on a scale on which 5 denotes perfect conditions) would be rated as less than 3 on the same scale here. This impression is confirmed by the recently published statement of another astronomer who has visited both the Lick and the Lowell observatories. The conclusion I draw from this fact and from M. ANTONIADI's experience is that the visibility of the geometrical canal system at Flagstaff and its non-visibility at Mount Hamilton and Meudon are not due to superior atmospheric conditions in Arizona.

For the present, then, we must be content to let the question remain open and simply state that the visual observations of the past year are as contradictory as those of previous oppositions, though the weight of evidence, on the whole, is this year more favorable to the theory that the markings on *Mars* are of natural origin.

You will recall that attempts were made as long ago certainly as 1892 to photograph *Mars*. But these early experiments were not very successful. It is only within the last few years that improvements in photographic processes have really brought the planet within the reach of the camera. Excellent

MARS, OCTOBER 14, 1909; DRAWN BY E. M. ANTONIADI.

MARS, OCTOBER 19, 1909; DRAWN BY E. M. ANTONIADI.

work in this respect, as in visual observation, has been done at the Lowell Observatory and very successful photographs have there been taken. Mr. LOWELL is on record to the effect that these photographs confirm the visual observations in showing geometrical canals. But in this, as in his visual results, he has not been able to convince all capable areographers. The slide now thrown on the screen, for example, is a drawing which records all the trustworthy detail that M. ANTONIADI could see on the photographs of *Mars* taken by Mr. LOWELL on July 11, 1907. It is obvious that this drawing does not support the geometrical theory.

During the recent opposition of the planet, photographs were made not only at Flagstaff, but at Mount Wilson and at the Yerkes Observatory, by Messrs. HALE and BARNARD, and also by MM. LA BAUME PLUVINEL and F. BALDET, who mounted a double telescope on the Pic-du-Midi in France—a station whose elevation and excellent atmospheric conditions gave promise of good results. This double telescope consisted of a reflector of one-half meter aperture and a refractor of one-fourth meter aperture carried on the same mounting. With it eighty plates showing 1,350 images of *Mars* were obtained. The observers say that these photographs show nearly all the details visible in a telescope, but of the system of geometrical canals, "we have not been able to find a trace upon our plates."

The beautiful slides[1] kindly sent me by Professors BARNARD and HALE, as you see, also fail to show this system, though they exhibit much delicate detail.

Further advances in the photographic art will undoubtedly be made, and within a few years the art may reach such perfection that this troublesome "canal" question will be definitely settled by its aid. At present we can only say, as we did of the visual observations, that the weight of evidence obtained in the past opposition favors the "natural" theory.

In the time that remains I wish to present some recent evidence bearing on the question whether it is possible by direct observation to demonstrate that water vapor exists in the Martian atmosphere. It is very generally accepted that the phenomena of the polar caps and the rare "clouds" observed on the terminator of *Mars* are due to water in the form of

[1] I regret that I cannot reproduce these photographs here.

vapor and in some frozen form,—hoar-frost, snow, or ice,—though other theories have been advanced. Aside from this evidence, we have at present no method of detecting the presence of water vapor on *Mars* except by means of the spectroscope.[1]

This is not the appropriate place, even if time permitted, to give an account of the many efforts that have been made to determine whether or not water-vapor absorption lines are present in the spectrum of *Mars*. The problem is by no means an easy one to work out, for the sunlight reflected to us by *Mars* must pass through our own atmosphere as well as his, and our atmosphere always contains more or less water vapor. The spectrum also contains a vast number of lines of purely solar origin intermingled with the atmospheric absorption lines. Great skill and care are needed to avoid the errors that may be introduced into the result by these confusing elements.

It is necessary to select water-vapor lines in those parts of the spectrum where the solar lines are comparatively few and relatively feeble, and to eliminate the absorption due to terrestrial water vapor by comparing spectra of *Mars* with spectra of the Moon, taken as nearly as possible at the same time and under the same conditions as to the instrument and as to the position of the bodies in the sky. The Moon is known to have no water vapor on its surface, hence the water-vapor absorption in its spectrum is due to our own atmosphere. Comparing the Moon's spectrum with that of *Mars*, we note whether or not the water-vapor lines in the latter are of equal or of greater intensity. If they are only of equal intensity, the investigation gives a negative result—there is no evidence of the existence of water vapor in addition to that known to be present in our own atmosphere.

Dr. CAMPBELL has recently published[2] an exhaustive critical review of all of the spectroscopic observations of *Mars* up to the opposition just past, and has shown that they have not given a conclusive answer to our question. Even the observations by Mr. SLIPHER at Flagstaff in 1908, from which Mr. VERY finds definite evidence of the existence of water vapor

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[1] A polariscopic method of detecting the presence of water vapor was suggested by Mr. N. H. PICKERING some years ago if I am not mistaken. I have, however, been unable to find the account of it.

[2] *Lick Observatory Bulletin*, No. 169.

in the atmosphere of *Mars*,[1] cannot be accepted without reservation, owing to the possibility that the intensification of the lines in the spectrum of *Mars* may be due to changes in the vapor content of our own atmosphere in the intervals of several hours that occurred between Mr. SLIPHER's photographs of the planet and those of the Moon.

You are aware of the fact that Dr. CAMPBELL has himself been one of the investigators of this question; that he obtained a negative result from his observations at Mount Hamilton in 1894 and that he has recently repeated these observations on the same general plan from a station on the summit of Mount Whitney, 14,501 feet above sea-level. This station was chosen because its elevation raised it above the major part of the water vapor in our own atmosphere and because at the time when *Mars* and the Moon could be observed[2] in quick succession at about the same altitude (and hence through the same layer of our own air) the air above the mountain was likely to be relatively dry. The results may best be stated in the observer's own words: "The conclusion drawn from this investigation, in view of the extreme faintness and apparent equality of the *a* bands [the water-vapor absorption lines in the part of the spectrum photographed] in the Martian and lunar spectra, as observed through a minimum of water vapor, is that the quantity of any water vapor existing in the equatorial atmosphere of *Mars* at the time these observations were made was too slight to be detected by present spectrographic methods."

Dr. CAMPBELL has kindly authorized me to give you a brief account of a still more recent investigation of this question, the results of which have not yet been published. You are aware of the fact that the spectroscope enables us to measure the radial velocities of light-giving bodies by means of the slight displacements of the spectral lines due to this motion. Conversely, then, if such a body is known to be in motion relatively to the Earth, we can determine which lines in its photographed spectrum are due to light from the body and which ones are due to absorption by our own atmosphere, by measuring the relative displacements of the lines. To do this

[1] *Lowell Observatory Bulletin*, **1**, 207, 221, 1909.

[2] The actual dates of observation were September 1 and 2, 1909.

with any accuracy requires a spectrograph of high dispersion, one, that is, which separates the various lines in the spectrum sufficiently to admit of accurate measures of their position. The spectrographs hitherto employed in the study of the Martian spectrum have had too low a dispersion to permit this principle to be used.

In the investigation now to be described a grating spectrograph was used, constructed on plans prepared by Dr. CAMPBELL, in conjunction with the 36-inch refractor. Its dispersion for what is known as the D region of the spectrum, when the second-order grating spectrum is used, is equal to that of the three-prism Mills spectrograph for the blue region of the spectrum.

With this powerful instrument Dr. ALBRECHT photographed the spectrum of *Mars* in January and February of the present year at a time when it was known, from the orbital motions of the two bodies, that the planet was receding from the Earth with a velocity of about 19 kilometers per second. On measuring the plates he found that the water-vapor and oxygen lines in this part of the spectrum showed a displacement with respect to the purely solar lines that corresponded to a relative velocity very closely equaling that of *Mars* with respect to the Earth. In other words, by their displacement relatively to the lines known to be of solar origin, the water-vapor and oxygen lines proclaimed their terrestrial origin. Further, when the micrometer was set to the positions the corresponding lines should occupy if caused by absorption in the Martian atmosphere, no trace of any lines could be seen.

In estimating the weight of this last statement we must remember, as Dr. CAMPBELL reminds us in his conclusions on the Mount Whitney observations, "that the rays as photographed had passed from the Sun through the planet's atmosphere, for the most part down to its surface, and out again to us, thus traversing the Martian atmosphere twice and multiplying any absorptive effect approximately by two."

I conclude, therefore, that up to the present time it has been impossible to demonstrate by any spectrographic method that water vapor exists in the atmosphere of *Mars*.

This does not prove its non-existence, be it noted. It only proves that its amount, if it exists, must be very small—much

less, probably, above unit area on *Mars* than in our atmosphere about the same area of Mount Whitney.

It is difficult to understand how so small an amount of water can keep a geometrical canal system on *Mars* in active operation.

March, 1910.

ON THE SPECTRUM OF *MARS* AS PHOTOGRAPHED WITH HIGH DISPERSION.

By W. W. Campbell and Sebastian Albrecht.

Let us recall that the solar spectrum, as viewed by terrestrial observers, is composite. Photospheric light, in passing out through the gases and vapors of the Sun's atmosphere, is selectively absorbed, with the result that many thousands of lines are introduced into the spectrum. These rays pass down through the Earth's atmosphere to the observer, and the absorption by water vapor and oxygen in the terrestrial atmosphere introduces many hundreds of additional lines, at definite points in the yellow, orange, and red regions. The observed spectrum of the Sun is in reality the spectrum of the Sun plus the spectrum of the Earth. The spectrum of the Moon, so far as our present problem is concerned, is simply this Sun-Earth spectrum.

The light from *Mars* is photospheric light, which passes out through the Sun's atmosphere, thence down through the atmosphere of *Mars* to the planet's crust, where a certain proportion is reflected out through the Martian atmosphere, and thence down through the Earth's atmosphere to the observer. The so-called spectrum of *Mars* is in reality the Sun's spectrum plus *Mars's* spectrum plus the Earth's spectrum.[1] Any water vapor and oxygen in the Martian atmosphere should introduce the same absorption lines which are introduced by the Earth's atmosphere in the Sun-Earth spectrum.

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[1] A little of the light would be reflected from the atmospheric strata of various heights without passing down to the planet's surface. It should also be noted that the rays do not pass normally through the planet's atmosphere, but have angles of incidence and reflexion with the strata equal on the average, in the present investigation, to about 20°.

If the distance between *Mars* and the Earth is not changing rapidly,[1] the water vapor and oxygen lines from *Mars* and the lines from the Earth will coincide. When this condition of coincidence exists, it is clearly a difficult problem to detect moderate quantities of water vapor and oxygen in the Martian atmosphere, for the evidence of Martian absorption will be overwhelmed by the absorption of the richly laden terrestrial atmosphere, especially if the observer be near sea-level. To hope for success, the observations should be made from a high-altitude station, at times when overlying air strata carry a minimum of water vapor, and when the planet is as near the zenith as practicable; observing the lunar spectrum, under identical conditions, for comparison.

Because of the faintness of the Martian and lunar spectra, it has been found that we are limited to low dispersion in visual observations, and that, when the distance between the two planets is constant or nearly so, low dispersion offers a more sensitive method than high dispersion, even when photography is employed.

Complying with the conditions in the two preceding paragraphs, the writers photographed the spectra of *Mars* and the Moon last September, from the summit of Mount Whitney. The conclusion drawn from that investigation was that the quantity of any water vapor then existing in the equatorial atmosphere of *Mars* was too small to be detected by the spectrographic methods available. This does not mean that the Martian atmosphere was carrying no water vapor, but only that the quantity must have been very small.

At times other than those when *Mars* is near opposition, the Earth and *Mars* are relatively approaching or receding from one another. Their relative velocity at quadrature may amount to 20^{km}, more or less, per second, depending upon the concurrence of favorable circumstances.

When Mr. CAMPBELL was photographing the spectrum of *Mars* in December, 1896, with a Rowland grating, fourth order,[2] 568 lines per millimeter (14,438 per inch), he realized that the Doppler-Fizeau principle offers great advantages, in

[1] More accurately, if the spectrographic velocity of *Mars* with reference to the Earth is constant or nearly so. This takes into account the relative velocity of *Mars* and the Sun.

[2] *Astrophysical Journal*, 5, 236, 1897.

theory at least, for solving the problem of the Martian atmosphere, for on photographs of the spectrum, made near quadrature, with sufficiently high dispersion, the Martian absorption lines and the terrestrial absorption lines should be separated. At that time (thirteen years ago) the method could not succeed, for all the prominent water vapor and oxygen lines are in the region on the red side of λ 5875, and the photographic dry plates then available were not sufficiently sensitive to record this region. Even in the fairly sensitive region λ 5700-λ 5800 the grating spectrograms of *Mars* were underexposed. The successes of recent years in sensitizing dry plates to yellow, orange, and red light have encouraged the present effort to apply the method.

A spectrograph, designed by Mr. CAMPBELL to meet the requirements of the problem and used in connection with the 36-inch refractor, contains an excellent Michelson five-inch plane grating (15,000 lines per inch) which gives a brilliant spectrum in the second order on one side, and this was utilized. The wooden mounting of the spectrograph was designed at all points to resist differential flexure during the intervals of exposure to the planet and to the Moon. The instrument was adjusted, the observations were secured, and the measures and reductions of the spectrograms were all made by Mr. ALBRECHT.

It was planned to secure observations of *Mars* and the Moon on or near January 17, 1910, as the planet was in quadrature at that time. The spectrographic velocity of *Mars* with reference to the Earth was then 18.8^{km} per second, recession. Unfavorable weather delayed somewhat the carrying out of the program, but fortunately the velocity remained nearly constant for several weeks, until satisfactory observations were secured.

With the spectrograph adjusted for the orange region, which is rich in water-vapor absorption lines, spectrograms of *Mars* were secured on January 26th and 27th under poor atmospheric conditions, and on February 2d under excellent conditions, our atmosphere on that night being exceedingly dry. Measures of the available water-vapor lines on these spectrograms, eight to twenty-two in number, establish that they were displaced with reference to the lines of solar origin in the observed Martian spectrum by amounts on the three dates corresponding to velocities in the line of sight

of 18.6, 19.1, and 17.8^{km} per second. The relative velocities of *Mars,* computed from our knowledge of the orbits of the Earth and *Mars,* amounted to 19.1^{km} per second. The discrepancy of 0.7^{km} per second is within the probable errors of the results yielded by the individual lines. The dispersion employed was such that the water-vapor lines originating in our atmosphere and any originating in *Mars's* atmosphere should have appeared side by side, though not clearly separated. If the absorptions by the two planets were equal, the two sets of lines of equal intensities should, in effect, have appeared as broad lines of double width, and the measured velocities should have been but half the computed velocities. The facts are that the terrestrial lines were not bordered nor increased in width by companion lines. When the micrometer wire was set successively in positions which Martian absorption lines would occupy, no traces of absorption were found in these positions. In effect, Martian absorption did not exist to such an extent as to be visible in the spectrum, or to influence the measurements referred to.

With the spectrograph adjusted to the so-called "alpha" region at λ 6280, which includes a large number of oxygen absorption lines, two spectrograms were obtained on February 3d. The observable oxygen lines, seven and six in number, were displaced with reference to the lines of solar origin by amounts corresponding to velocities in the line of sight of 18.8 and 17.4^{km} per second. The velocity computed from the elements of the orbits amounted to 19.1^{km}. The discrepancy of 1.0^{km} is likewise within the unavoidable error of measurement. Here again the terrestrial oxygen lines were not bordered nor doubled in with by Martian lines. When the micrometer was set in the positions for favorable Martian lines, no absorption was visible at these places.

The conclusions to be drawn from this investigation are: The quantity of any water vapor existing above unit area in the equatorial atmosphere of *Mars* was certainly less than one fifth that existing about Mount Hamilton under the excellent conditions prevailing on February 2d. The air temperature was 0° Centigrade, the relative humidity 33%, the absolute humidity 1.9 grams per cubic meter, and the zenith distance 55°. Likewise, the quantity of oxygen above unit area of *Mars* must be small in comparison with that in the Earth's atmosphere.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1910.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter...	May 2, 5^h 30^m A.M.	New Moon ...	June 7, 5^h 16^m A.M.
New Moon	" 8, 9 33 P.M.	First Quarter.	" 14, 8 19 A.M.
First Quarter..	" 15, 6 13 P.M.	Full Moon ...	" 22, 12 12 P.M.
Full Moon	" 23, 9 39 P.M.	Last Quarter..	" 29, 8 39 P.M.
Last Quarter...	" 31, 2 24 P.M.		

Two of the four eclipses of the year will occur during May. A total eclipse of the Sun occurs on May 8th, but will not be visible in any part of the United States. The region of partial eclipse extends over the South Indian and South Pacific oceans, but the only well-known land in the track of totality is Tasmania, and on this island the eclipse is total at about sunset, when the Sun is too low for valuable observations.

A total eclipse of the Moon on the night of May 23d-24th will be visible throughout the United States. The principal phases are about as follows, Pacific time:—

Moon enters shadow	May 23, 7^h 46^m	P.M.
Total eclipse begins.......	9 9	P.M.
Middle of the eclipse......	9 34	P.M.
Total eclipse ends	10 0	P.M.
Moon leaves shadow	11 22	P.M.

The Sun reaches the summer solstice and summer begins about midnight June 21st-22d, Pacific time.

Mercury is in fine position for evening observation during the first half of May. On the first of the month it remains above the horizon nearly two hours after sunset. It comes to greatest east elongation on the morning of May 2d, and then the Sun and planet begin to approach each other, but rather slowly at first, so that up to the middle of the month the planet does not set until more than an hour after sunset. The approach becomes more rapid and inferior conjunction is reached on the morning of May 25th. The planet then becomes a morning star and recedes from the Sun. By the middle of June the planet will rise about an hour before sunrise,

and this condition will continue for the rest of the month, greatest west elongation being reached on June 19th. The conditions for visibility as a morning star during the latter half of June are not very good, but it may possibly be seen in the morning twilight on an exceptionally clear morning.

Venus is a morning star, and rises a little less than two hours before sunrise on May 1st and a little more than two hours before at the end of June. The planet passed greatest west elongation toward the end of April, and its apparent distance from the Sun is slowly diminishing, but the relative motion of the two bodies in declination causes a temporary increase in the interval between the risings of the two bodies. This will continue until some time in July. There will be a very close conjunction between *Venus* and *Saturn* on the morning of June 5th about 6 o'clock Pacific time. The apparent distance between the bodies will be only 4′, which is not greatly different from the limit of naked-eye separability. The time of nearest approach is after sunrise throughout the United States, so we cannot see it with the naked eye, but it will be a fine phenomenon for people in Alaska and the Sandwich Islands.

Mars is still to be seen in the evening sky, although it has lost nearly all the brightness it had during the summer and autumn of 1909. On May 1st it sets at about 11 P. M.; on June 1st shortly after 10 P. M., and on July 1st shortly after 9 P. M., less than two hours after sunset. During the two-months' period it moves from the western part of *Gemini* through that constellation into *Cancer*, about 44° eastward and 5° southward. About June 1st it is a few degrees south of *Castor* and *Pollux*, the brightest stars in *Gemini*. It is well along toward its greatest distance from the Earth and its brightness is in consequence nearly at its minimum, but it will be as bright as the pole star and there will be no difficulty about seeing it.

Jupiter on May 1st is above the horizon until nearly 4 A. M., passing the meridian a little before 10 P. M. At the end of June it sets a little before midnight. It is therefore in fine position for evening observation throughout the period. It is in the western part of the constellation *Virgo* and moves slowly westward about 1° until June 2d. It then begins to

move eastward among the stars and at the end of the month it is about where it was on May 1st.

Saturn is a morning star, having passed conjunction with the Sun on April 16th, and does not get far enough away from that body for naked-eye visibility until after the middle of the month. At the end of June it rises shortly after 1 A. M. It moves about 6° eastward and 2° northward from *Pisces* into *Aries*. Its conjunction with *Venus* on June 5th has already been mentioned.

Uranus rises shortly after midnight on May 1st and at about 8:30 P. M. on June 30th. It is in the eastern part of *Sagittarius*, and moves somewhat more than 1° westward during the two months. No bright star is near it, and therefore it is not very easily identified.

Neptune is in the western sky in the evening in the constellation *Gemini*. On May 29th *Mars* passes about 2° to the north.

(SIXTY-EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. ZACCHEUS DANIEL, of Princeton, New Jersey, for the discovery of an unexpected comet on December 6, 1909.

Committee on the Comet-Medal:

W. W. CAMPBELL,
SIDNEY D. TOWNLEY,
HEBER D. CURTIS.

SAN FRANCISCO, March 19, 1910.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE RELATION BETWEEN THE SEPARATION AND THE NUMBER OF VISUAL DOUBLE STARS.[1]

In the course of my double-star survey I have been impressed with the fact that the number of close pairs discovered far exceeds the number of pairs separated by moderate distances. More than 70 per cent of the 3,500 pairs so far discovered in this work have measured distances of 2″ or less, and about 50 per cent distances of 1″ or less.

We should, of course, expect to find an excess of apparently close double stars, on the assumption that the binary systems are distributed in space with approximate uniformity; the systematic character of the survey and the fact that a larger percentage of the easier pairs has been discovered by earlier observers are also large factors in producing the observed excess. But the question arises, whether the closer double stars are not actually as well as apparently more numerous.

To investigate this question counts were made of all the double stars in Part I of BURNHAM's "General Catalogue of Double Stars within 121° of the North Pole," and also of all the double stars found on the Lick Observatory charts of the sky north of + 36° declination, omitting a very few charts that have not yet been compared with the sky. In the former count only stars having one component as bright as 9.5 magnitude were included; in the latter only those in which the double-star system (i. e., both components combined) was as bright as 9.0 B. D. magnitude. In both counts only pairs as close as or closer than 5″.0 were included.

The stars were tabulated according to distance by half-seconds of arc in both counts, and, according to brightness, by whole magnitudes in the count from the catalogue and by half-magnitudes in the count from the charts, the stars brighter

[1] Abstract of *Lick Observatory Bulletin*, No. 176.

than 6.0 being included in a single group in each case. After tabulating the results, the effect of parallax was taken into account, and by the use of appropriate factors, derived from KAPTEYN'S researches on the average parallaxes of the stars, the numbers of each distance class were formed on the assumption that all of the double stars were removed from us to the distance,—in the first case of the average star of 8.5 magnitude, in the second case of 8.75 magnitude.

The first count included 6,973 pairs, or, neglecting those in which both components are as faint as 9.1 magnitude, 5,809 pairs. The second count includes 2,169 pairs in a sky area containing 44,634 stars of 9.0 B. D. magnitude or brighter.

The figures in each of the two tables (here omitted) show very clearly—(1) that the actual number of close double stars greatly exceeds the number with moderate distances between the components, and (2) that the increase in number progresses with the decrease in separation.

By comparing the total numbers of double stars of the various orders of magnitude in the second count with the total numbers of B. D. stars of corresponding magnitudes in the sky area examined, it also appears that one star in thirteen or fourteen of those as bright as 8.0 B. D. magnitude is a double star under 5".0, while among the stars between 8.0 and 9.0 magnitude the ratio is only 1 to 25. This would seem to indicate either that the number of visual double stars under 5".0 is greater among the brighter stars or that a larger percentage of the latter has been discovered. The latter alternative would strengthen our first conclusion, stated above. The fact that the observations of CAMPBELL, FROST, and others have shown that one star out of five or six of those with well-determined radial velocities is a spectroscopic binary, and that the average magnitude of the known spectroscopic binaries, excluding the variable stars, is about 4.0, makes the ratios just given at least of interest if not of significance.

March, 1910. R. G. AITKEN.

NEW DOUBLE STARS.

In the course of my regular double-star work I have recently found closer companions to the three double stars Σ 772, Σ 1064, and Ho 357. In the first star each component proves to be a

close pair; in the other two it is the principal component that is now resolved.

I have also found that the bright star ρ *Geminorum* (4.2 magnitude), which precedes *Castor* about 1°.4, has a faint companion less than 3″ distant from it. As the principal star has a proper motion of 0″.23 in the direction 31°.4, the measures of the next two years will decide whether or not this is a physical system.

The mean results of my measures of these four systems are:—

Σ 772.

R. A. $5^h\,36^m\,5^s$; Decl. $+21°\,32'$

	Angle.	Dist.	Mag.		
1910.10	115°.9	0″.38	9.1 — 9.8	3^n	A and B New
1910.10	212 .1	1 .40	9.1 — 13.2	3	C and D New
1910.10	243 .1	30 .21	8.6 — 9.1	3	A B and C = Σ 772

Σ 1064.

R. A. $7^h\,12^m\,26^s$; Decl. $-11°\,51'$

	Angle.	Dist.	Mag.		
1910.14	336°.4	0″.30	7.7 — 7.7	2^n	A and B New
1910.10	240 .2	15 .64	7.0 — 9.5	1	A B and C = Σ 1064

ρ *Geminorum.*

R. A. $7^h\,22^m\,41^s$; Decl. $+31°\,59'$

	Angle.	Dist.	Mag.	
1910.19	11°.4	2″.80	4.2 — 12.5	2^n

Ho 357.

R. A. $8^h\,47^m\,48^s$; Decl. $+26°\,40'$

	Angle.	Dist.	Mag.		
1910.15	254°.6	0″.32	6.9 — 8.0	3^n	A and B New
1910.13	4 .2	38 .79	6.6 — 12.0	1	A B and C = Ho 357

There is no evidence of change in the wide Struve pairs, but the distance of the Hough pair is increasing, probably by the proper motion of the bright pair.

R. G. Aitken.

March 12, 1910.

Note on Halley's Comet.

Halley's Comet at the end of April was a fairly conspicuous object in spite of the strong moonlight, rising over two hours ahead of the Sun. On the morning of April 29th its effective

magnitude was estimated by Mr. OLIVIER to be 1.8, and the tail could be made out for eight or ten degrees. Numerous photographs have been made of it with the Crossley Reflector and with the Crocker cameras. In general, the head has been "umbrella-shaped," often showing well-marked concentric envelopes. The edges of the tail are much brighter than the center, which has occasionally been marked by a dark lane. The tail is of the streamer type, and both it and the details about the head change in aspect from night to night, but sudden changes and condensations do not appear. A very faint secondary tail is shown on the plate of April 29th, starting about two degrees from the head and making an angle of about fifteen degrees with the main tail. Some evidence is seen also of a faint jet directed toward the Sun.

H. D. CURTIS.

NOTE ON THE ORBITS OF COMETS HALLEY, *a* 1910, AND *e* 1909 (DANIEL).

The orbits of these three comets have recently been computed in the Berkeley Astronomical Department, and have yielded most satisfactory results from the standpoint of tests for Professor LEUSCHNER'S methods of deriving differential corrections for the removal of residuals. The character of the orbits is different in all three cases. Halley's Comet furnishes an example for a very long arc in the case of a nearly parabolic orbit; Comet *a* 1910 for a parabola from both a short arc with unequal intervals, and a moderate arc having one position at the very trying place near perihelion with a very small heliocentric distance; and Comet *e* 1909 (DANIEL) furnishes an example for an ellipse of about six years' period from a moderate arc. The last also illustrates very neatly the great adaptability of the method in that the computers carried on the work for both parabola and general conic at the same time, with comparatively little extra labor.

The elements of Halley's Comet were computed by R. T. CRAWFORD and W. F. MEYER from observations of 1909 September 17, 1909 December 16, and 1910 February 28. They are:—

$$T = 1910 \text{ April } 19.67760 \text{ Gr. M. T.}$$

$$\left.\begin{array}{l} \omega = 111^\circ \; 43' \; 09''.32 \\ \Omega = \; 57 \;\; 16 \;\; 18 .09 \\ i = 162 \;\; 12 \;\; 55 .57 \end{array}\right\} 1910.0$$

$$\log e = 9.985\ 5082$$
$$\log a = 1.252\ 5224$$
$$\log q = 9.768\ 6346$$

The perturbations due to the action of *Mars* at its nearest approach to the comet, during January, 1910, were computed and found to be ineffective.

The elements of Comet *a* 1910 were computed by W. F. MEYER and Miss SOPHIA H. LEVY. The first set was derived from observations of February 1st, 2d, and 5th. The final set was based upon observations of January 18th, February 5th, and March 13th. They are:—

$$T = 1910 \text{ January } 17.0888 \text{ Gr. M. T.}$$

$$\left.\begin{array}{l} \omega = 320^\circ \; 54' \; 40''.3 \\ \Omega = \; 88 \;\; 47 \;\; 24 .1 \\ i = 138 \;\; 46 \;\; 47.9 \end{array}\right\} 1910.0$$

$$q = 0.128980$$

The largest residual for this orbit is 3″. An observation of April 13th, by AITKEN, shows the residuals—

$$\text{O}-\text{C} \left\{ \begin{array}{r} \cos\delta\,\Delta\alpha = -0^s.9 \\ \Delta\delta = -4'' \end{array}\right.$$

An orbit for Comet *e* 1909 (DANIEL), showing a period of 7.15 years, was derived by STURLA EINARSSON and R. YOUNG from observations of December 11th, 15th, and 18th. A longer arc became available so that their final elements depend upon observations of 1909 December 7, 1909 December 18, and 1910 March 3. They are:—

$$T = 1909 \text{ November } 28.7238 \text{ Gr. M. T.}$$

$$\left.\begin{array}{l} \omega = \; 3^\circ \; 28' \; 43''.9 \\ \Omega = 70 \;\; 59 \;\; 43 .4 \\ i = 19 \;\; 26 \;\; 48 .1 \end{array}\right\} 1910.0$$

$$e = 0.602481$$
$$\mu = 547''.5362$$
$$\log a = 0.541063$$
$$\text{Period} = 6.48030 \text{ years}$$

All three cases required the use of LEUSCHNER's closed expressions for δf and δg, which worked admirably.

R. T. CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, April 21, 1910.

New Spectroscopic Binaries.

The following forty-two binaries have recently been discovered during the progress of the spectrographic work at the Lick Observatory and at the observatory of the D. O. Mills Expedition, Santiago, Chile. They are taken from *Lick Observatory Bulletins,* Nos. 173, 177, and from a Bulletin soon to be issued by Dr. Moore:—

Star.	α		δ		Range.	Discoverer.
λ *Hydri*	0	45.1	−31°	57′	−12 to + 6km	Mrs. Moore
υ *Piscium*	1	14.0	+26	44	− 1 to +22	Albrecht
π *Ceti*	2	39.4	−14	17	+ 8 to +21	Moore
κ *Persei*	3	2.7	+44	29	+27 to +32	Campbell and Albrecht
δ *Fornacis*	3	38.3	−32	15	−25 to +64	Moore
b *Persei*	4	10.7	+50	3	− 4 to +52	Curtis
γ *Mensæ*	5	35.8	−76	25	+54 to +62	Mrs. Moore
ξ *Columbæ*	5	52.1	−37	8	+55 to +66	Mrs. Moore
δ *Canis Majoris*	7	4.3	−26	14	+33 to +36	Wright
27 *Canis Majoris*	7	10.2	−26	10	+86 to +115	Albrecht and Paddock
h¹ *Puppis*	8	7.8	−39	19	+17 to +30	Mrs. Moore
h² *Puppis*	8	10.5	−40	2	+12 to +28	Mrs. Moore
θ *Hydræ*	9	9.2	+ 2	44	−20 to + 7	Campbell and Albrecht
δ *Antliæ*	10	24.9	−30	6	Both spectra	Curtis
ρ *Leonis*	10	27.5	+ 9	49	+35 to +58	Campbell
α *Ursæ Majoris*	10	57.6	+62	17	− 4 to −10	Campbell
π8 *Virginis*	11	55.7	+ 7	10	−21 to +18	Albrecht
θ^1 *Crucis*	11	58.0	−62	45	− 1 to −26	Mrs. Moore
η8 *Corvi*	12	26.9	−15	38	−12 to +18	Albrecht
β *Crucis*	12	41.8	−59	8	+ 6 to +25	Wright
ξ^2 *Centauri*	13	1.0	−49	22	− 9 to +44	Moore
D. C. 6501	13	30.3	+37	42	+ 2 to +14	Wright and Allen
h *Centauri*	13	47.4	−31	47	− 9 to +25	Paddock
η *Centauri*	14	29.2	−41	43	−11 to + 6	Wright
α *Lupi*	14	35.2	−46	57	0 to +17	Albrecht
κ *Centauri*	14	52.6	−41	52	+ 4 to +17	Curtis and Paddock
d *Lupi*	15	29.0	−44	37	− 2 to +20	Paddock
χ *Lupi*	15	44.6	−33	19	Both spectra	Paddock
γ *Apodis*	16	18.1	−78	4	+ 2 to + 8	Wright
χ *Ophiuchi*	16	21.2	−18	14	−11 to +22	Campbell and Albrecht
υ *Scorpii*	17	24.0	−37	13	− 2 to +38	Wright
σ *Draconis*	18	49.7	+59	16	− 6 to −20	Burns
υ *Draconis*	18	55.6	+71	10	− 3 to −13	Burns
η *Lyræ*	19	10.4	+38	58	− 2 to −13	Albrecht
τ *Draconis*	19	17.5	+73	10	−27 to −34	Albrecht
ϵ *Draconis*	19	48.5	+70	1	0 to + 6	Campbell
θ^1 *Sagittarii*	19	53.2	−35	33	−15 to +15	Paddock
θ *Cephei*	20	27.9	+62	40	−14 to + 7	Moore

Star.	α		δ		Range.	Discoverer.
σ Cygni	21	13.5	+38	59	— 2 to — 12	CAMPBELL
ζ Capricorni	21	20.9	—22	51	— 4 to + 5	CAMPBELL and ALBRECHT
D. C. 9701	22	9.5	+39	13	— 9 to — 14	ALLEN
ζ Sculptoris	23	57.2	—30	16	— 18 to + 13	PADDOCK

W. W. CAMPBELL.

APPOINTMENT OF DR. ALBRECHT.

Dr. SEBASTIAN ALBRECHT, Fellow in the Lick Observatory, University of California, 1903-06, Assistant 1906-08, and Assistant Astronomer 1908-, has been appointed First Astronomer in the Argentine National Observatory at Cordoba. Dr. PERRINE, Director of the Córdoba Observatory, is to be congratulated upon securing the services of Dr. ALBRECHT, whose departure from Mount Hamilton will be regretted by all, for both scientific and personal reasons. Dr. ALBRECHT expects to leave Mount Hamilton on or shortly after July 1st.

W. W. CAMPBELL.

GENERAL NOTES.

Ephemeris of Halley's Comet.—

(Continued from preceding number.)

Greenwich Midnight.	R. A.			Dec.		log r	log Δ
1910 June 1	9^h	55^m	57^s	$+2°$	$1'.3$	0.0243	9.7190
5	10	11	6	$+0$	38.0		
9	10	20	47	-0	14.3		
13	10	27	52	0	53.3	0.0948	9.9906
17	10	33	27	1	24.4		
21	10	38	8	1	51.1		
25	10	42	17	2	14.8	0.1547	0.1508
29	10	45	56	2	36.8		
July 3	10	49	24	2	57.8		
7	10	52	41	3	18.2	0.2063	0.2617
11	10	55	50	3	38.2		
15	10	58	53	3	58.3		
19	11	1	51	4	18.3	0.2513	0.3441
23	11	4	56	4	38.4		
27	11	7	39	4	58.5		
31	11	10	27	-5	19.0	0.2910	0.4078

This ephemeris was computed by Mr. F. E. SEAGRAVE (*Observatory*, March, 1910).

Transit of Halley's Comet.—Mr. C. S. TAYLOR, in *Nature*, February 17th, points out that the altitude of the Sun at the North Cape on May 18th, the day of the transit of Halley's Comet, will be $1° 9'$, and the contact does not take place till $16^h 6^m$ local time. As the altitude of the Cape is 968 feet, there would be a fair chance of seeing whatever there may be to see.

Recent calculations indicate that this transit will be invisible in Europe and the greater part of America. The calculated times of ingress and egress for the Pacific Slope are as follows:—

First contact, May 18, $6^h 22^m$ Pacific Standard Time
in position angle 264°
Last contact, May 18, $7^h 22^m$ Pacific Standard Time
in position angle 92°

More accurate values of the elements may, however, change these values considerably.

The daily press records the departure for Honolulu of Mr. ELLERMAN, of the Mount Wilson Solar Observatory, under the auspices of the Astronomical and Astrophysical Society of America, aided by a grant from the National Academy of Sciences. Mr. ELLERMAN is equipped with a 6½-inch equatorial telescope and mounting loaned by the Lick Observatory, and subsidiary apparatus for cometary photography, and his purpose is to fill the observational gap of nearly one third of the Earth's circumference covered by the Pacific Ocean and make possible the securing of as continuous as possible a series of photographs of this comet at the time of its maximum brightness.

Professor KR. BIRKELAND, of the Universitets Fysiske Institut, Christiania, will proceed to Kaafjord in Finmarken at the northern end of Norway, in order to take magnetic and atmospheric observations during the period from May 7th to June 1st, in connection with the transit of Halley's Comet across the Sun's disk and the possible passage of the Earth through the tail. Mr. O. KROGNESS will act as his assistant.

The Oxford University authorities have decided to confer the honorary degree of doctor of science on Mr. PHILIP HERBERT COWELL, F. R. S., chief assistant, and Mr. ANDREW CLAUDE DE LA CHEROIS CROMMELIN, assistant at the Royal Observatory, Greenwich, in recognition of their conjoint successful labors in the exact determination of the reappearance of Halley's Comet.—*London Standard.*

Comet a 1910.—Comet *a* 1910 is now (April 15th) within telescopic reach in the morning sky. It is not brighter than the twelfth magnitude, and a very indistinct and difficult object. Plates taken with the Crossley Reflector on April 11th and 12th show a head between one and two minutes of arc in diameter, with a slight condensation at the center, but with no trace of a tail.

H. D. CURTIS.

Notes from "Science."—The council of the Royal Astronomical Society has awarded the gold medal of the society to Professor F. KÜSTNER, director of the University Observatory of Bonn.

Lord RAYLEIGH has been elected a foreign associate of the Paris Academy of Sciences in succession to the late SIMON NEWCOMB.

Sir WILLIAM HUGGINS, F. R. S., the eminent astronomer, celebrated his eighty-sixth birthday on February 7th at his residence at Tulsehill, England.

Dr. HENRY WILDE has offered the University of Oxford the sum of £600 for the foundation of an annual lecture on astronomy and terrestrial magnetism, in honor and memory of EDMUND HALLEY, some time Savilian professor of geometry.

Sir CHARLES TODD, F. R. S., well known for his astronomical and meteorological work in South Australia, has died at the age of eighty-three years.

Professor W. J. HUSSEY, director of the observatory of the University of Michigan, announces that the observatory is about to receive gifts aggregating $20,000 from Mr. R. P. LAMONT, of Chicago, a member of the class of '91. One gift, representing $17,000, is a deed of land directly east of the observatory, bordering upon the arboretum. This should always insure a sky line free from smoke and dust. Mr. LAMONT has also furnished funds to start the construction of a 24-inch refracting telescope.

The Rev. CARR WALLER PRITCHETT, formerly director of the Morrison Astronomical Observatory and president of Central College and Pritchett College, Missouri, died on March 18th, at the age of eighty-seven years.

A friend of Allegheny Observatory has endowed a fellowship in astronomy at that institution. The fellow is to receive $500.

The Silliman Lectures, 1909-1910.—The Silliman Lectures in Yale University for the academic year 1909-1910 were delivered by Director W. W. CAMPBELL, in the interval January 24 to February 2, 1910. The subjects of the eight lectures were as below, the general subject being "Stellar Motions," with special reference to motions determined by means of the spectroscope:—

I. *Historical and Introductory.*—Theory of spectroscopic measurement of the radial velocities of celestial bodies. Visual applications of the method. Types of spectra to be dealt with.

II. *Development of the Photographic Method.*—Conditions required to obtain accurate results. Proofs that observed motions are correct. Conditions other than motion affect results.

III. *Results Obtained for Individual Stars* (general consideration of the solar-motion problem).—Comparison of results obtained at different observatories. Accuracy attainable for stars of various magnitudes and spectral types. Velocities of groups of stars in different areas of the sky. Introduction to the solar-motion problem.

IV. *Proper Motion Determinations of the Motion of the Solar System.* —Consideration of the principal methods and results. Systematic motions of the stars.

V. *Spectrographic Determinations of the Solar Motion.*—Advantages of the method. Development of theory. Selection of materials for solution of problem. Recent results for direction and speed of solar motion.

VI. *Other Products of the Spectrographic Method.*—Systematic motions of the stars. Orders of magnitude of stellar velocities and average velocity. Relation between brightness and velocity. Distances of the stars.

VII. *Visual and Spectrographic Double Stars.*—Visible double stars, introductory to invisible double and multiple stars discovered by means of the spectrograph. Discovery and study of spectroscopic binary stars.

VIII. *Spectrographic Study of Variable Stars* (general consideration of stellar problems).—Application of radial-velocity method to study of variable stars. Current and future problems of the stellar system.

Presentation of the Gold Medal.—The annual general meeting of the Fellows of the Royal Astronomical Society was held February 11th at Burlington House. The President, Sir DAVID GILL, was in the chair. Professor FRIEDRICH KÜSTNER, of the Royal Observatory, Bonn, to whom the Council awarded the gold medal of the society, was present.

The president said the gold medal had been awarded to Professor KÜSTNER for his catalogue of stars, his pioneer determination of the aberration constant from motions in the line of sight, and his detection of the variation of latitude. Astronomy in one sense or another appealed to minds of widely different orders. To the mathematician it offered problems of infinite interest; but, as they all knew, there had been most distinguished workers in the field of astrodynamics to whom the spectacular glories of the heavens did not appeal—to whom the first sight of an object like *Saturn* or a great star cluster as viewed through a good telescope brought no thrill, no insatiable desire to see more, or to acquire or devise means for so doing. Such men were too apt to regard the art of observing as a mere mechanical operation that was unworthy of their practical study. But they were thus frequently placed in the position of having to employ observations about which they had not the capacity to distinguish between the good and the bad.

There was a larger number of persons who were not wanting in the

emotional response to their first telescopic sight of celestial objects; some of them acquired, or were driven to construct, instruments to indulge their awakened curiosity; and not a few of them afterwards did useful work as astronomical observers. The attributes of the great majority of astronomers lay between these two extremes. But the number of men who possessed the true fire and natural capacity for the most refined original research in the field of astronomy was limited. Such men must have an inborn natural mathematical, mechanical, and manipulative aptitude; the critical faculty to discern the possible sources of error to which any class of observations might be liable, with the inventive capacity to devise means for their elimination; and that persistent patience and divine discontent with their own best efforts which alone could lead to the highest and most refined class of work. Their medallist was supremely a man of this latter type. (Hear, hear!) The greatest teacher of practical astronomy since the days of BESSEL was unquestionably WINNECKE, and he fully realized the fact that the true, practical astronomer was "born, not made." Their medallist was one of the first to enter the small but brilliant school conducted by WINNECKE at Strassburg, about forty years ago, and since then he had touched no department in the wide field of astronomical research which he did not adorn. (Hear, hear!)

After the presentation of the gold medal to Professor KÜSTNER, a number of interesting photographs and drawings of the comet, taken at Oxford, Cambridge, Dunsink, and other places were exhibited.—*The Times,* February 12, 1910.

Historical Note.—Mr. GEORGE MADEIRA, mineralogist and mining engineer of Healdsburg, California, has supplied me with the following interesting information: "In the year 1860 I erected the first astronomical observatory and installed the first astronomical telescope in the State of California, at Volcano, Amador County, some 2,200 feet above the sea. . . . The telescope, with its equatorial mounting and delicate clock-work motion, was made by TEBOURS & SECRETAN, of Paris, France. It was of only three inches aperture and the highest power was but 125. . . . I was a youth in 1860, and an enthusiast in astronomical studies. Professor TELERAND was my instructor, a thorough mathematician; and for two years, while he was with me, the Volcano Observatory ran day and night. . . . On June 30, 1861, a superb comet, unheralded, appeared in the west after the Sun had passed below the mountain ridge. I had been observing some large spots on the Sun and really saw the comet an hour before the Sun had set. I ran to TELERAND's home, shouting, 'I have discovered a huge

comet.' . . . In an instant the telescope was turned on the comet, and the clockwork set in motion. We saw a large coma with a bright central nucleus, the coma in a violent state of ebullition. The Sun soon went down, and then we saw the luminous tail stretching backward across the heavens for 20,000,000 miles. . . . 'We are passing through the tail of the comet,' exclaimed Mr. TELERAND. . . . There was a golden glow, extending quite to the horizon's line both north and south. A few small meteors fell during the night, no other results being observable. We must have been in the line of the comet's tail for twenty-four hours, as on the succeeding night the golden halo was perceptible."

W. W. CAMPBELL.

Book Catalogue.—WILLIAM WESLEY & SON, booksellers and publishers, of 28 Essex Street, Strand, London, have recently issued a very comprehensive classified catalogue of manuscripts, books, and pamphlets on astronomy. There are over 3,600 entries in the catalogue, containing many rare books from the libraries of Captain W. NOBLE, E. CROSSLEY, Miss A. M. CLERKE, and A. A. COMMON. It is noticed that a complete set of the *Astronomische Nachrichten* now costs over $600. The price of the catalogue is one shilling.

NEW PUBLICATIONS.

Bergstrand, Östen. Sur le mouvement du deuxième satellite d' Uranus, Umbriel. Uppsala and Stockholm. 1909. 8°. 19 pp. Paper.

Brendel, Martin. Theorie der kleinen Planeten. Zweiter Teil. Berlin. 1909. Folio. 192 pp. Paper.

Cannon, Annie J. Maxima and minima of variable stars of long period. Annals of the Astronomical Observatory of Harvard College, Vol. LV, Part II. Cambridge. 1909. Folio. 291 pp. Paper.

Evershed, John. The spectrum of sunspots. Madras. 1909. Folio. 54 pp. Paper.

Fagerholm, Erik. Undersökningar öfver stjärnhopen G. C. 341. Uppsala and Stockholm. 1909. 8°. 123 pp. Paper.

King, Edward S. Photographic magnitudes of seventy-six stars. Annals of Harvard College Observatory, Vol. LIX, No. V. Folio. Pp. 127-155. Paper.

Meridian-Beobachtungen von Sternen in der Zone 65°-70° nördlicher Declination. Von H. Geelmuyden and J. Fr. Schroeter. Kristiana. 1909. Folio. 320 pp. Paper.

Neue Annalen der K. Sternwarte in München. Katalog von 1,436 Sternen, hauptsächlich Zenitsternen. München. 1909. Folio. 242 pp. Paper.

Nordlund, J. O. Photographische Ausmessung des Sternhaufens Messier 37. Uppsala and Stockholm. 1909. 8°. 148 pp. Paper.

Observations of major planets made with the heliometer at the Royal Observatory, Cape of Good Hope, during the years 1897 to 1904. Edinburgh. 1909. Folio. 87 pp. Paper.

Pickering, Edward C. Durchmusterung zones observed with the 12-inch meridian photometer. Annals of the Astronomical Observatory of Harvard College, Vol. LXX. Cambridge. 1909. Folio. 23 pp. Paper.

Sampson, Ralph Allen. A discussion of the eclipses of *Jupiter's* satellites, 1878-1903. Annals of the Astronomical Observatory of Harvard College, Vol. LII, Part II. Cambridge. 1909. Folio. 343 pp. Paper.

Stratton, F. J. M. The constants of the Moon's physical libration. Memoirs of the Royal Astronomical Society, Vol. LIX, Part IV. London. 1910. Folio. Pp. 257-290. Boards.

Wendell, Oliver C. Photometric observations made with the 15-inch east equatorial during the years 1892 to 1902. Annals of the Astronomical Observatory of Harvard College, Vol. LXIX, Part I. Cambridge. 1909. Folio. 97 pp. Paper.

Minutes of the Meeting of the Board of Directors of the Astronomical Society of the Pacific, held in the Assembly-Room of the Chamber of Commerce of San Francisco, March 26, 1910.

Meeting was called to order by President W. W. Campbell. Other Directors present were R. G. Aitken, J. D. Galloway, Charles S. Cushing, Fremont Morse, Charles Burckhalter, and D. S. Richardson.

On motion, duly seconded and carried, the minutes of the preceding meeting, as printed in Publication No. 130, were approved without reading.

A communication from Professor L. Praika, of the Observatory of Nizbor, Bohemia, informed the Society that the first volume of the publications of that Observatory had been forwarded through the Smithsonian Institution, and asking that the Nizbor Observatory be put on our list of exchanges. Matter referred to the Library Committee, with power to act.

The following new members were elected:—

Ray A. Schuman, of Louisville, Ky.
Claude G. Conard, of Oakland, Cal.
George Otis Spencer, of San Francisco.
R. Young, of Mount Hamilton.

On motion of Mr. Cushing, seconded by Mr. Galloway, the matter of printing an index to the first twenty-one volumes of the *Publications*, in pamphlet form, was referred to a special committee, consisting of the members of the Committee on Publication and the President and Secretary of the Society, with power to act.

On motion, seconded and passed, the Secretary was instructed to address a communication to the Chamber of Commerce of San Francisco, expressing the thanks of the Society for the use of the Assembly Hall of the Chamber.

On motion of Mr. Aitken, seconded by Mr. Cushing, a resolution was passed, authorizing the Secretary, in his discretion, to drop from the rolls of the Society, the names of members whose dues remain unpaid for a period of three years.

The attention of the Board being directed to the fact that the number of publications printed at each issue was about twice the number put into circulation, a resolution was passed authorizing the Committee on Publication to investigate the matter, and, if it found that a saving could be made without impairing the usefulness of the Society, to take the necessary steps for effecting same.

Adjourned.

Minutes of the Twenty-Second Annual Meeting of the Astronomical Society of the Pacific, held in the Assembly Hall of the Chamber of Commerce of San Francisco on March 26, 1910.

President W. W. Campbell in the chair. By consent, the minutes of the preceding meeting were not read. The President called for Reports of Committees.

In the absence of Dr. S. D. Townley, Chairman of the Committee on the Donohoe Comet-Medal Awards for the year 1909, the report of that committee was read by the Secretary, as follows:—

Report of the Donohoe Comet-Medal Committee for the Year 1909.

The following comets were discovered during the year 1909:—

Comet *a* 1909, an unexpected comet, discovered independently by M. A. Borrelly, at Marseilles, on June 14, 1909, and by Mr. Zaccheus Daniel, at Princeton, on June 15, 1909. (It was Mr. Daniel's notice of discovery, with observed position, which was first communicated to the astronomers of this and other countries by telegraph and cable.)

Comet *b* 1909, Perrine's periodic comet, detected on its return by Dr. A. Kopff, at Heidelberg, on August 12, 1909.

Comet *c* 1909, Halley's periodic comet, detected (photographically) on its return by Professor Max Wolf, at Heidelberg, on September 11, 1909.

Comet *d* 1909, Winnecke's periodic comet, detected on its return by Professor F. Porro, at La Plata, on October 31, 1909.

Comet *e* 1909, an unexpected comet, discovered by Mr. Zaccheus Daniel, at Princeton, on December 6, 1909.

The Donohoe Comet-Medal of the Astronomical Society of the Pacific has been awarded to the two discoverers of Comet *a*, and to the discoverer of Comet *e*.

Respectfully submitted,

W. W. Campbell,
Sidney D. Townley,
Heber D. Curtis,
} *Committee.*

San Francisco, Cal., March 19, 1910.

Mr. Fremont Morse, Chairman of the Auditing Committee, reported that the accounts of the Treasurer for the preceding year had been examined and found correct.

Mr. J. D. Galloway, Chairman of the Committee on Nominations, reported the following names for Directors and Committee on Publication, to serve during the ensuing year:—

For Directors: R. G. Aitken, Chas. Burckhalter, W. W. Campbell, A. O. Leuschner, Wm. H. Crocker, Chas. S. Cushing, J. D. Galloway, Geo. E. Hale, E. J. Molera, Fremont Morse, D. S. Richardson.

For Committee on Publication: Sidney D. Townley, James D. Maddrill, Heber D. Curtis.

The Chair appointed Messrs. Cornish and Baird as tellers, and ballots were distributed, to be taken up and counted later in the evening.

The scientific programme of the evening commenced with a few remarks from the retiring President, Dr. W. W. Campbell, calling

attention to the fact that this was the twenty-first annual meeting of the Society. He then proceeded to deliver a most exhaustive address on "A Study of Spectroscopic Binary Stars," which was illustrated with lantern slides and carefully followed by an interested audience.

Astronomer R. G. AITKEN followed Dr. CAMPBELL in an address on "A Review of the Recent Observations of Mars," also illustrated and well received.

At the close of the addresses the ballots were counted and the results announced showed that the members above named had been elected to their respective places on the Board of Directors and the Committee on Publication.

Adjourned.

MINUTES OF THE MEETING OF THE NEWLY ELECTED BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, IN THE ASSEMBLY HALL OF THE CHAMBER OF COMMERCE, SAN FRANCISCO, CAL., ON THE EVENING OF MARCH 26, 1910.

The Board proceeded to organize by electing the following officers:—

President: FREMONT MORSE.

First Vice-President: GEORGE E. HALE.

Second Vice-President: J. D. GALLOWAY.

Third Vice-President: R. G. AITKEN.

Secretary and Treasurer: D. S. RICHARDSON.

Secretary on Mount Hamilton: R. G. AITKEN.

The following were elected members of the Library Committee: R. T. CRAWFORD, S. D. TOWNLEY, D. S. RICHARDSON.

It was moved, seconded, and carried that the interest from the Life Membership, John Dolbeer, and William Alvord funds for the year 1910 be turned into the General Fund and applied toward the cost of printing *Publications.*

On motion of Mr. CUSHING, duly seconded and carried, the Chairman of the Committee on Publication was instructed to confer with the Chairman of the Finance Committee concerning amounts which may be expended on PUBLICATIONS during the ensuing year.

Adjourned.

Report of the Treasurer of the Astronomical Society of the Pacific for the Fiscal Year Ending March 26, 1910.

GENERAL STATEMENT.

Liabilities.

To the William Alvord Fund	$ 5,008 56
" Alexander Montgomery Library Fund	3,789 46
" Donohoe Comet-Medal Fund	757 97
" Bruce Medal Fund	2,780 22
" Life Membership Fund	1,974 36
" John Dolbeer Fund	5,000 00
" General Fund	948 77
Total	$20,259 34

Assets.

Bonds on deposit with Mercantile Trust Co.	$14,418 02
Cash in Humboldt Savings Bank	331 94
" Savings and Loan Society	437 06
" Union Trust Company	970 28
" German Savings and Loan Society	974 36
" Security Savings Bank	630 44
" San Francisco Savings Union	757 97
" Mutual Savings Bank	790 50
" Donohoe-Kelly Banking Company	948 77
Total	$20,259 34

Transactions of the Astronomical Society of the Pacific for the Fiscal Year Ending March 26, 1910.

WILLIAM ALVORD FUND.

Dr.

To Balance March 27, 1909		$ 5,008 56
Bond Interests for year	$200 00	
Humboldt Bank Interests	13 50	
Savings and Loan Society Interests	17 64	231 14
		$5,239 70

Cr.

By Bond Interests transferred to General Fund	$200 00	
Bank Interests transferred to General Fund	31 14	231 14
Balance March 26, 1910		$5,008 56

BRUCE MEDAL FUND.

Dr.

To Balance March 27, 1909	$ 2,652 94
Bond Interests for year	100 00
Interests Mutual Savings Bank	27 28
Balance March 26, 1910	$ 2,780 22

DONOHOE COMET-MEDAL FUND.

Dr.

To Balance March 27, 1909	$ 727 68
Interests San Francisco Savings Union	30 29
Balance March 26, 1910	$ 757 97

ALEXANDER MONTGOMERY LIBRARY FUND.

Dr.			
To	Balance March 27, 1909		$ 3,818 51
	Bond Interests for year	$150 00	
	Interests Security Savings Bank	26 80	176 80
			$ 3,995 31
Cr.			
By	Transfer to General Fund on account rent	$120 00	
	Transfer to General Fund on account salary	60 00	
	Books purchased	25 85	205 85
	Balance March 26, 1910		$ 3,789 46

LIFE MEMBERSHIP FUND.

Dr.			
To	Balance March 27, 1909		$ 1,924 36
	Bond Interests for year	$40 00	
	Interests German Savings and Loan Society	35 27	
	From C. D. Perrine	50 00	125 27
			$2,049 63
Cr.			
By	Bond Interests transferred to General Fund	$40 00	
	Interests German Savings and Loan Society transferred to General Fund	35 27	75 27
	Balance March 26, 1910		$ 1,974 36

JOHN DOLBEER FUND.

Dr.			
To	Balance March 27, 1909		$ 5,000 00
	Bond Interests for year	$190 00	
	Interests Union Trust Company	35 94	225 94
			$ 5,225 94
Cr.			
By	Bond Interests transferred to General Fund	$190 00	
	Interests Union Trust Co. transferred to General Fund	35 94	225 94
	Balance March 26, 1910		$ 5,000 00

GENERAL FUND.

Dr.			
To	Balance March 27, 1909		$ 853 56
	Dues for year—		
	1907	$ 15 00	
	1908	20 00	
	1909	314 85	
	1910	543 19	893 04
	Sale of *Publications*		13 48
	Refund on Library Insurance		3 00
	Life Membership Fund		125 27
	John Dolbeer Fund		225 94
	William Alvord Fund		231 14
	Alexander Montgomery Library Fund, on account of—		
	Salary	$ 60 00	
	Rent	120 00	
	Books	25 85	205 85
	Total		$ 2,551 28

Cr.

By C. A. Murdock & Co., for printing, including *Publications* 125 to 130 inclusive	$807 95	
Salary of Secretary and Treasurer	240 00	
Rent	220 00	
Furniture	97 00	
Postages	39 95	
Lantern service March 27, 1909	12 00	
Miscellaneous printing	27 60	
Stationery	5 00	
Sign on office door	1 50	
Moving books from Berkeley	11 00	
Insurance on library	7 90	
Engraving comet medals	3 76	
Crocker safe deposit box	4 00	
Mercantile Trust Company	14 00	
Dr. R. G. Aitken for index	30 00	
Students' Co-operative Society, books	25 85	
Dues refunded to Alexander	5 00	
Transfer to Life Fund, account Perrine	50 00	$ 1,602 51
Balance		$ 948 77

FUNDS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD IN DEPOSIT BY THE MERCANTILE TRUST COMPANY OF SAN FRANCISCO, AT 464 CALIFORNIA STREET.

These securities are all of the face denomination of $1,000, and the values given represent their original cost to the Society.

Life Membership Fund.

One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937; interest payable in January and July	$ 1,000 00

Alexander Montgomery Library Fund.

One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932; interest payable in January and July	1,040 00
One Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bond, No. 641. Principal due October, 1929; interest payable April and October	1,084 02
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665, Principal due January, 1915; interest payable January and July..	1,035 00

Bruce Medal Fund.

One Bay Counties' Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1636. Principal due September, 1930; interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922; interest payable in March and September	977 22

John Dolbeer Fund.

One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937; interest payable in January and July	1,000 00
One Oakland Transit Consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932; interest payable January and July	1,040 00

John Dolbeer Fund—Continued.	
One Bay Counties Power Company's 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1637. Principal due September, 1930; interest payable in March and September	$1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837. Principal due September, 1922; interest payable March and September	977 22
William Alvord Fund.	
Two Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bonds, Nos. 656 and 657. Principal due October, 1929; interest payable in April and October	2,168 06
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915; interest payable in January and July	2,071 50
Total, 14 bonds, value	$14,418 02

Respectfully submitted,

D. S. Richardson,

Secretary and Treasurer.

We have examined the foregoing report and find the same to be correct.

Frémont Morse,

Charles S. Cushing,

Auditing Committee.

OFFICERS OF THE SOCIETY.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first qurter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publicaion. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 748 Phelan Building, San Francisco, California. Subscription price, $5.00 per year.

FIG. I.—COMET HALLEY, MAY 9, 1910.
$14^h\ 47^m$ — $15^h\ 47^m$ P.S.T.
Willard 5-inch lens.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XXII. SAN FRANCISCO, CALIFORNIA, JUNE, 1910 No. 132

PHOTOGRAPHS OF HALLEY'S COMET MADE AT THE LICK OBSERVATORY.

BY HEBER D. CURTIS.

In the interval from September 12, 1909, to July 7, 1910, Halley's Comet was photographed at the Lick Observatory on ninety-five nights, with a total of three hundred and seventy negatives, distributed as follows:—

Crossley reflector	206 plates
Willard 6-inch lens	66 "
Willard 5¼-inch lens	52 "
Zeiss planar	25 "
Lantern lens	19 "
Dallmeyer 6-inch lens	2 "

The constants for the various instruments used are as follows:—

Instrument.	Aperture.	Focal length.	1 inch =	Focal ratio.
Crossley	36.00 in.	210.1 in.	16′.4	1 : 5.8
Willard 6-inch	6.00	30.8	1°.9	1 : 5.3
Dallmeyer 6-inch	6.00	32.5	1 .8	1 : 5.5
Willard 5¼-inch	5.25	25.9	2 .2	1 : 4.9
Zeiss planar	1.62	6.1	9 .4	1 : 3.9
Lantern lens	1.62	5.0	11 .6	1 : 3.0

The Dallmeyer lens, mounted on the Crocker photographic telescope, was used for only two plates. A few plates were taken also with the Willard six-inch camera on the same mounting, but after February 11th the latter lens was removed from the Crocker telescope, and all the cameras mentioned above, with the exception of the Dallmeyer, were mounted on the tube of the Crossley reflector. The earlier plates taken with the Crossley were obtained by guiding on a star and moving

the cross-wires one second of arc at intervals calculated to allow for the motion of the comet in right ascension and declination. As soon as the comet became bright enough for the purpose a guiding telescope of 3.5 inches aperture and 211.5 inches focal length was employed, at first with illuminated wires and later with dark wires when the brightness of the nucleus permitted this course. In anticipation for the need of guiding on the comet with the telescope as a whole instead of the usual moving plate the reflector had been dismounted in January and special anti-friction roller bearings installed in both the polar and declination axes. These worked perfectly, and the guiding with the long finder was entirely satisfactory as regards responsiveness and delicacy, though the moving parts weigh over six tons. As the long finder is of practically the same focal length as the reflector, no flexure was experienced, and the guiding for the smaller instruments mounted on the massive tube was naturally far more accurate than would have been possible with the shorter finder of the Crocker telescope.

Several different brands of plates were used during the work; the earlier plates were in general Seed 27 or Cramer Crown. When the tail developed sufficiently, Cramer Instantaneous Isochromatic plates were tried because the comet was relatively so strong in visual light. These plates gave on the whole the best results during this period, and were used with but few exceptions throughout the time of greatest brightness. After the comet became fainter Lumiere "Sigma" plates were employed for the most part. The guiding telescope was so set that the Crossley plates show the head and about 40′ of the tail; the Willard lenses were mounted on the cube of the reflector tube so as to displace the head about six degrees from the center of the plate and take in twelve to fifteen degrees of the tail; the short focus lenses were mounted at the upper end of the tube. When the tail became too long to be recorded with the Zeiss and lantern lenses (extreme fields of about 45° and 35° respectively) the latter was shifted so as to take in only the outer and fainter portions of the tail. When the time available for exposure permitted, two shorter exposures were made with the Willard 6-inch simultaneously with a long ex-

posure with the 5¼-inch. Four or more plates were generally made with the reflector on each night. One or two of these were quite short to obtain the details of the inner coma and nucleus, one or two were made with exposures from five to fifteen minutes, and another with an exposure as long as possible, the shorter exposures being made at times when the commencement of morning or evening twilight would have rendered a long exposure unsafe. Five, and on a few occasions six, plates were exposing at once, the one guiding serving for all the instruments, with due precautions as to shutting off exposure while plates were being changed. The plates taken while the lenses were mounted on the Crocker telescope were made by C. P. OLIVIER, Fellow, who later assisted in guiding for many of the plates taken with the Crossley and attached cameras.

It is proposed to publish later a complete list of all the Lick Observatory photographs of Halley's Comet with more detailed measurements of the features of the head, position-angles of the tail, structure of the envelopes, etc. In this preliminary paper space permits only a brief summary of some of the more salient points in this practically unbroken photographic record, with notes on a few of the more striking plates.

NUCLEUS.

It is probable that the nucleus was sharp and stellar throughout this portion of the apparition period, though the photographic record shows a number of marked deviations from this condition,—deviations perhaps more apparent than real. On a number of dates when the head was evidently in a condition of intense activity no sharp central condensation appears even on short exposures, the whole inner coma being so bright as to mask entirely on the photographic plate any nucleus, if such existed. It is evident that the decision as to the existence of a stellar nucleus on such doubtful dates must rest with visual observations made with large refractors. A few notes will show the variations observed photographically:—

1909, Sept.	12	Nucleus 3″ to 4″	= 6000 miles
	13	3	= 5000 "
	22	2	= 2900 "
Nov.	14	3	= 2400 "
Dec.	13	9	= 5600 "

1910, Jan.	7	Nucleus 4″	= 2600	miles
Feb.	4	7	= 5500	"
Mar.	3	4	= 4000	"
Apr.	12	10	= 6400	"
	23	5	= 2300	"
May	1	4	= 1400	"
	5	3	= 800	"
	9	5	= 1000	"
	1[illegible]	10+		
	14	None		
	15	None		
	20	7″	= 400	"
	22	4	= 300	"
	23	3	= 290	"
June	1	4	= 1000	"
	11	6	= 2300	"

Dr. AITKEN's measure of 2″.6 on May 10th would correspond to an actual diameter of about 470 miles.

COMA.

The inner coma and parts immediately about the nucleus have varied greatly from night to night. Small sharp jets have been frequent, on several occasions showing a beautiful spiral effect. Bright, strong appendages and wings were frequent at the time of greatest brightness, generally asymmetrical and irregular. The phenomena have been exceedingly varied; in fact, so intricate are the details of the head on many of the plates that any verbal description is difficult and inadequate. It is hoped that it may be possible to publish later a fairly complete series of reproductions covering the more interesting plates. Figure II[1] shows the remarkable nuclear appendages on the morning of May 14th (civil date). At this time the head and envelopes were markedly asymmetrical, the south side being much the stronger. The nucleus appears elongated, and from its rear proceed two remarkable wings nearly as bright as the nucleus itself; one of these is almost in the axis of the tail and is about 50″ long; the other makes an angle of 59° with the axis of the tail and is 70″ in length. An interval of nearly fifty minutes separates the times of mid-exposure for the first and last Crossley plates of this date, but there is very

[1] Unfortunately these appendages, though very distinct on the negatives, can be made out only with great difficulty in the published cut.

FIG. II.
May 13, $15^h\ 58^m\ 30^s$ P.S.T.
Crossley Reflector.

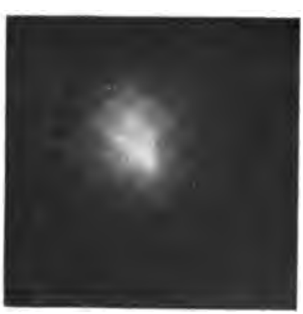

FIG. III.
May 23, $8^h\ 19^m$ — $8^h\ 20^m$ P S.T.

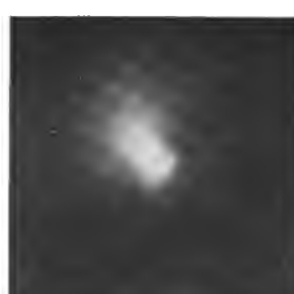

FIG. IV
May 23, $10^h\ 17^m$ — $10^h\ 19^m$ P.S.T.

Crossley Reflector, enlarged three times.

little if any change apparent in the appendages in this interval.

There are numerous cases where the plates of a given date show evidence of change and movement in the parts about the nucleus, but time has not yet permitted measurement and discussion of such plates. A case of very rapid change, almost explosive in character, is illustrated in Figures III and IV. Both plates were taken with the Crossley reflector on the evening of May 23d; the first was exposed one minute and the second two minutes, one hour and fifty-nine minutes apart. On the former plate the nucleus is quite sharp at the rear, and strong jets proceed from it on the side toward the Sun at an angle of 60° with the axis of the tail. These jets give a spiral effect to the head and are so bright at the nucleus that this appears wedge-shaped. In the next figure very bright growths, roughly spherical, have formed on each side of the nucleus, with a slightly fainter patch at the rear which joins the two globes of matter. From edge to edge the new growth measures $37'' = 3{,}570$ miles. The photographic diameter of the brightest part of the nucleus on the first plate is $3'' = 290$ miles; this may well be considerably larger than the true nucleus. A plate exposed from 8:31 to 8:49 P. S. T. shows the nucleus as still sharp and with no trace of the appendages. On the next plate, exposed from 8:55 to 9:55 P. S. T., the head is so bright as to mask considerably any details about the nucleus, which appears less sharp and roughly spherical, with an estimated diameter of $12'' = 1{,}160$ miles. The succeeding plate was exposed for ten seconds at 10:15 P. S. T. The nucleus here is sharp; small but faint traces of the outer parts of the new growths can be seen, apparently detached from the nucleus. These globular appendages seem then to have reached their full growth in the interval of about fifty minutes from 9:30 to 10:18 P. S. T., though the interval may be considerably shorter than this. Under this assumption the lower limit of the velocity of movement outward within 20″ of the nucleus was 0.88^{km} per second, and it may well have been considerably higher. It would be of interest to trace this growth farther and to search for the remnants of this formation along the tail on the following day. May 24th, however, was the only date between May 20th

and June 12th when clouds entirely prevented photographic observations, and the plates of May 25th show no condensations or anomalous features in the tail at some distance from the head.

The type form of the head has been that showing interlacing streamers and envelopes, fairly stable in character and not changing with great rapidity. On such a typical plate there will be in general three envelopes, with fairly well-marked boundaries. A fine plate taken with the Crossley on the morning of May 5th (civil date) shows envelopes more symmetrical than usual; the brightest envelope has its vertex 40″ from the nucleus; the second 80″; the third, which is very much fainter, at 140″. Outside of this can be glimpsed still fainter matter, making the total diameter of the head across the nucleus about 8′ = 137,000 miles. On the plates of May 14th (civil date) the head is remarkable for its lack of symmetry. The envelopes are confused and interlacing; the south side of the head is much stronger; irregular wings form the continuation of the brighter inner envelope and extend to a distance of 18′ from the nucleus on the southern side; a curious vacant spot 2.5′ in diameter is left by the curving streamers on the side toward the Sun and slightly displaced to the north. The diameter of the head across the nucleus is 15′ = 118,000 miles; the central part of the tail is dark. On May 23d the head is made up of spiral streamers, giving a "pin-wheel" effect. After passing the Sun in May a new feature developed in the coma in the shape of a bright spherical halo or aureola, which apparently is distinct in material and formation from the regular envelopes. On May 23d and 26th the total recorded photographic diameter of this halo was 34′ = 194,000 miles, and it was frequently so bright as to blot out many of the details of the inner coma.

The measured photographic diameters of the head of the comet are subject, of course, to the varying exposure conditions, and for a study of the variation in the size of the head as it approached the Sun such results must be used with caution. For the fainter, outer portions of the head rapid, short-focus lenses will give the most reliable data, and even with these it is probable that visual observations with large instruments will be the more trustworthy, unless long-exposure times are a possibility. The improvements in the telescope

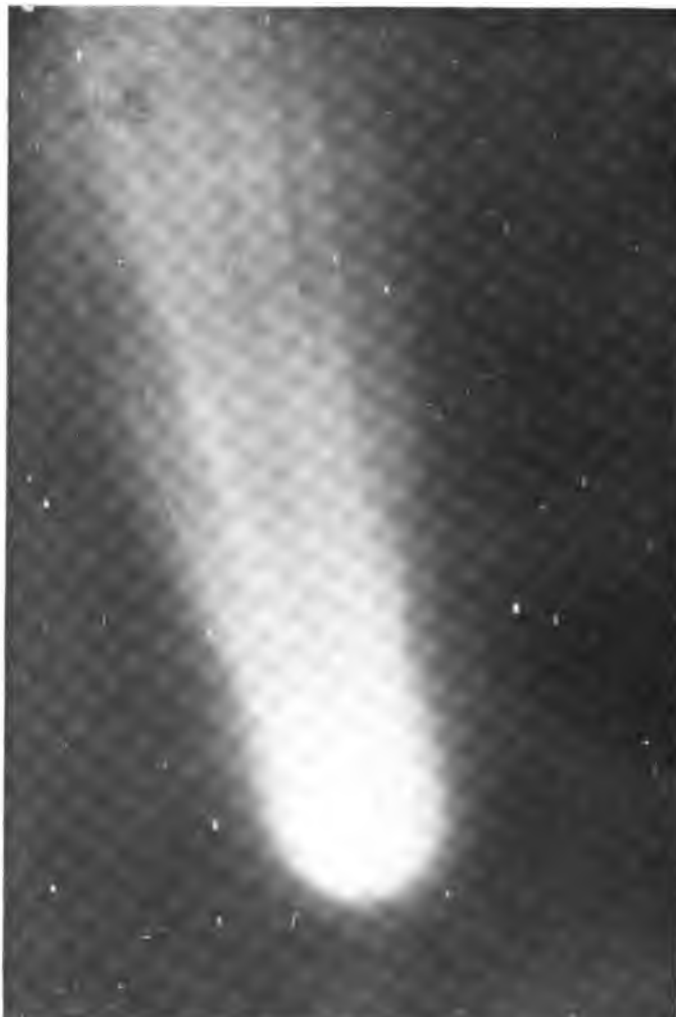

FIG. V.—May 1, $15^h\ 42^m$ — $16^h\ 5^m$ P.S.T.
Crossley Reflector.

FIG. VI.—May 5, $15^h\ 17^m$ — $15^h\ 53^m$ P.S.T.
Crossley Reflector.

bearings were not completed in time to make the taking of such small-scale photographs a possibility during the time when guiding by an auxiliary telescope was impossible owing to the faintness of the comet, but it is expected to secure a series of photographs illustrating the increase in diameter as the comet recedes from the Sun. The most reliable evidence as to the size of the halo about the head in December is that given by Dr. AITKEN's measure of 15′ ($\Delta = 1.36$) = 550,000 miles. The following table gives the recorded photographic diameters on a number of selected dates:—

1909,	Sept.	12	13,000	miles
	Dec.	14	220,000	"
1910,	Jan.	7	79,000	"
		28	181,000	"
	Feb.	4	141,000	"
		11	170,000	"
		28	153,000	"
	Apr.	19	129,000	"
		28	118,000	"
	May	1	122,000	"
		5	161,000	"
		23	194,000	"
		31	315,000	"
	June	2	308,000	"
		8	340,000	"

TAIL.

The portions of the tail near the head have shown great variety and frequent change. Before May 18th the center is generally marked by a dark lane and much of the streamer effects seem to come from the envelopes. Later, the center was more usually occupied by streamers, frequently in a forked or fan effect, proceeding from the nucleus; on June 10th the center of the tail was again dark and the two main streamers appear to come from the ends of the bright inner envelope. The streamer effect near the head is shown in the Crossley plates reproduced in Figues V and VI, though much of the delicacy and beauty of the original negatives is naturally lost in the process of reproduction. Before May 18th the results from the portrait and short-focus lenses show in general a tail of the streamer type, usually quiescent and frequently entirely featureless beyond 5° from the head. Figure I gives a good

idea of the appearance of the tail at this time.[1] The southern edge has almost always appeared as stronger and fairly sharply defined, fading out to invisibility on the northern side. During this period also the envelopes frequently curve back into the main tail and interlace with the nuclear streamers. The lantern lens camera showed on the morning of May 6th (civil date) a fine tail 28° long, which has a great fork commencing at 8° from the head; at 24° from the head the extreme width is 4°. On June 1st the short-focus lenses show a tail 27° long, 3° wide at the outer end, and slightly curved to the north; this slight curve is seen on later plates also. Since May 25th the tail has shown much greater activity than it displayed earlier, and numerous instances are afforded for determining the amount of the motion of recession along the tail. Perhaps the most striking case is that afforded by the plates of June 6th, 7th, and 8th, of which the plates of June 6th and June 7th are reproduced in Figures VII and VIII.

The striking feature on June 6th was the anomalous streamer of great intensity to the south of the main tail; it starts at 1°.61 from the nucleus and its head is rounded and quite sharply defined; it makes an angle of roughly 15° with the main tail and is traced on the Zeiss plate to a distance of 16° from the nucleus. No trace of this great streamer is shown on the plates of June 5th, though there is a small streamer near the nucleus which may have been the source, and its sudden formation is something of a puzzle unless it is assumed that it may be the central part of the tail of June 5th displaced or rotated around to the south. Its brightness, however, and the enormous velocities necessary to form the new central portion of June 6th are against this hypothesis. The streamer has a slightly twisted and spiral appearance, with faintly marked convolutions. On the next night, June 7th, this streamer has moved over till it lies approximately in the axis of the tail; the spiral appearance has increased so that it now has a pronounced zig-zag effect. The strong central formation of the 6th has also moved out, and the remarkable fact is that this has also assumed a zig-zag shape and its convolutions are *parallel* to those of the

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[1] The small hooks seen on the star trails are not due to defects in guiding, but to the effects of differential refraction at the low altitude to which the exposure was frequently continued.

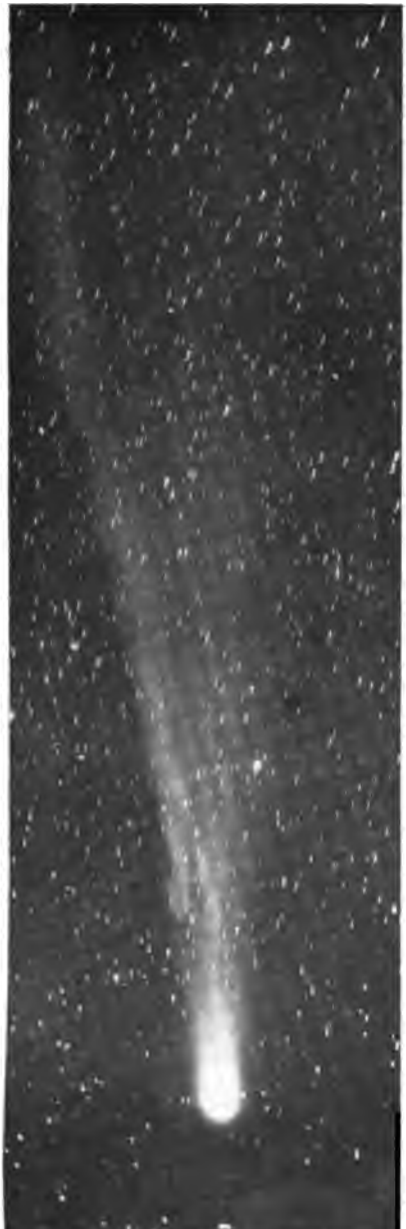

Fig. VII.
June 6, $8^{h}\ 50^{m}$ — $10^{h}\ 55^{m}$ P.S.T.

Fig. VIII.
June 7, $8^{h}\ 47^{m}$ — $10^{h}\ 47^{m}$ P.S.T.

Willard 5-inch lens.

southern stream. Twenty-four hours later, or forty-eight hours after the plate of June 6th, the plate of June 8th shows the end of the formation with one or two of the zig-zags still faintly visible at a distance of about 6°.6 from the head. From two plates taken with the Willard six-inch on June 6th at an interval of sixty-three minutes, the end of the great streamer shows a movement along the tail in the radius vector of 44 kilometers per second; in the interval of twenty-four hours between the plates of June 6th and June 7th the average velocity of the matter in the end of the streamer was 70.1^{km} per second; in the nearly equal interval between the plates of June 7th and June 8th the average velocity of recession along the tail for the same mass of matter was 91.2^{km} per second. Other interesting evidences of rapid motion along the tail are found in nearly the entire series from May 25th to June 3d. Measures have been made of the more striking features on these plates and are tabulated below in the order of their distances from the head, the unit being the Earth's distance from the Sun. This table is admittedly only preliminary; there are numerous other formations on the plates besides those measured; time has not yet permitted, however, the definitive working through of the large amount of material available for the study of the velocities along the tail. For this reason a discussion of the motions observed and the acceleration will be withheld for more definitive treatment later. These preliminary results are ample, however, to show the increase in velocity as the matter recedes from the head. In computing these velocities the tail has been assumed to be in the prolongation of the radius vector; the determination of the hyperbolic orbits of the matter will, of course, change these values.

TABLE OF VELOCITIES ALONG THE TAIL.

Date	D (limits)	D	Interval	Velocity, kilometers per second
May 23	. . . .	0	$3,000^s$	0.9
May 13-14	0.0018-0.0046	0.0032	86,670	4.9
May 27-28	0.0005-0.0080	0.0042	86,880	12.8
May 25-26	0.0043-0.0157	0.0100	88,260	19.3
June 2-3	0.0055-0.0239	0.0147	86,520	31.8
May 28-29	0.0080-0.0292	0.0186	86,190	36.8
May 31-Jun. 1	0.0095-0.0287	0.0191	86,220	33.3

Date	D (limits)	D	Interval	Velocity, kilometers per second
June 6[1]	0.0230-0.0237	0.0234	7,200?	48±
June 6	....	0.0237	3,180	43.8
May 26-27	0.0157-0.0383	0.0270	88,020	38.4
June 6-7	0.0236-0.0640	0.0438	86,070	70.1
June 7	....	0.0640	3,630	53.6 (doubtful)
May 30-31	0.0501-0.0922	0.0712	86,670	72.4
June 7-8	0.0640-0.1170	0.0905	86,700	91.2

The following are the lengths of tail as determined from the photographs on a few of the dates:—

				Miles
1909, Dec.	16	3′	=	430,000
1910, Jan.	28	1°	=	4,700,000
Feb.	4	1 .7	=	8,800,000
Apr.	21	4	=	9,200,000
Apr.	30	14	=	19,000,000
May	5	28	=	27,800,000
May	10	38	=	24,400,000
May	17	105	=	18,900,000
May	19	146	=	18,600,000 (visual determination)
May	23	59	=	16,000,000
May	28	28	=	17,600,000
June	2	20	=	21,000,000
July	1	4	=	18,000,000

On account of the moonlight, observations were suspended on June 12th and resumed on June 26th. The comet was last seen with the naked eye on the night of June 28th; its effective brightness at this time was not greater than that of a sixth magnitude star. Its continued activity at this time is noteworthy. On July 1st, when one hundred and forty one million miles from the Earth and one hundred and fifty-two million miles from the Sun, the tail was recorded on the lantern lens plate for about four degrees, corresponding to an actual length of eighteen million miles. The tail on this night showed as a broad fork with vertex at the head.

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[1] From comparison with Professor BARNARD's Yerkes plate of same date, as published in the *Monthly Evening Sky Map* for July.

PASSAGE THROUGH THE TAIL.

This question cannot be decided definitively until measures have been made on the formations and shape of the tail, the acceleration derived, and the hyperbolic paths of the matter forming the tail computed. The Mount Hamilton series from May 23d to June 8th shows many evidences of motion; these formations, however, and this increased activity are doubtless due to the same matter which caused such extraordinary changes in Comet Morehouse, as shown by the wave-lengths obtained by Professor WRIGHT with the objective spectrographs. It will accordingly be unsafe to deduce the shape of the tail before May 18th from the motions observed later. There will be needed also a collation and comparison of all available visual observations from May 18th to May 22d at observatories in different longitudes. A few such observations are at present available and a brief summary of them may be of interest; the times are Greenwich Mean Time.

May 18.5 (Helwan). Tail to *α Equulei;* 8° wide at *γ Pegasi;* 2° wide at *α Equulei.*

May 18.6 (Johannesburg). Tail to *θ Aquilæ;* southern branch observed.

May 19.0 (Mt. Hamilton). Two branches; the northern and stronger has *α Pegasi* on its northern edge and is about 6° wide, passing over *θ Aquilæ* with a width of 4°; faint traces suspected on the other side of the Milky Way by one observer. The southern and much fainter branch is about 3° wide; passes just south of the "Y" in *Aquarius,* with *α* and *β Capricorni* on its two edges. Total width about 17°.

May 19.1 to 19.3 (Königstuhl-Heidelberg). Bishop's ring seen about Sun; twilight described as of unusual intensity and duration. Very strong Bishop's ring seen about Moon. Appearances described as somewhat similar to those seen after the eruptions of Krakatoa and Mt. Pelée.

May 19.5 (Helwan). Tail goes past *θ Aquilæ* to Milky Way; tapering; 15° broad at *α Pegasi.*

May 19.6 (Breslau). Two faint arcs of light observed to pass over northern sky; 3° to 4° wide; upper one brighter; details of positions and movements in *Astronomische Nachrichten,* 4414.

May 19.7 (Johannesburg). Tail fainter; nearly to Milky Way; 11° broad in *Pegasus;* a degree or two farther north than the day before.

May 20.0 (Mt. Hamilton). Tail much fainter than the previous morning; 12° broad in *Pegasus,* 4° in *Aquila;* could not be made out east of γ *Pegasi;* not bright at horizon; resembled a detached streamer; about 1° north of the position of the day before.

May 20.3 (Helwan). No tail visible in west.

May 20.6 (Helwan). Tail in east to Milky Way; 10° broad in *Pegasus.*

May 20.6 (Johannesburg). Tail very faint; 10° broad in *Pegasus.*

May 20.7 (Mt. Hamilton). Perhaps 20° of tail visible in west in strong moonlight and twilight. Recorded for several degrees on plates.

May 21.0 (Mt. Hamilton). No trace of tail in east.

May 21.2 (Helwan). Tail to 20° in west.

May 21.6 (Helwan). No trace of tail in eastern sky.

May 21.6 (Johannesburg). Faint broad tail seen in east by two observers; no trace seen by another observer.

May 21.7 (Mt. Hamilton). 20° to 30° of tail in west.

May 22.0 (Mt. Hamilton). No trace of tail in east.

These observations are in some respects contradictory, and data from the longitudes of Australia, New Zealand, and Hawaii will be awaited with interest.

In connection with the possibility of the passage of the Earth through a part of the tail, the following points may be considered:—

1. The tail was of more than sufficient length to reach to the Earth throughout the period from May 5th to June 2d.

2. In the period from April 1st to July 1st the cometocentric latitude of the Earth did not reach 8°. Hence the tail appeared nearly straight during this time, and any attempts to determine the curvature of the tail by projecting the formations on the orbital plane are subject to large errors. For the same reason the measured angular diameters of the tail during this period probably represent closely the angular width of the tail in a

direction perpendicular to the orbital plane, provided the tail was not in the form of a flat sheaf; the photographs, however, seem to indicate that the tail was, at least within 10° of the head, a roughly circular bundle of streamers before May 15th.

3. The angular distances from the head corresponding to 15,000,000 miles have been computed for plates between May 10th and 15th and between May 23d and 28th. The average diameter of the tail at this point, including formations apparently north or south of the main tail, was 1,400,000 miles. Any ordinary assumption as to lag should affect the results on each side of May 18th about equally; if, as seems probable, the tail was straighter after this date than before, owing to the presence of lighter material, the average diameter will be larger than the figure given.

4. The distances of the Earth from the plane of the comet's orbit were as follows:

May 17.5 G.M.T.	+ 552,000	miles
18.5	+ 65,000	"
19.5	— 417,000	"
20.5	— 901,000	"
21.5	— 1,392,000	"

5. For a number of plates before and following May 18th the position of the radius vector has been plotted upon the negatives; for plates taken on May 9th, 10th, 11th, and 14th the lag behind the radius vector at the point of probable meeting of Earth and tail was on the average 12,000,000 miles for the apparent center of the strongest part of the tail. On the Zeiss plate of May 15th the main branch of the tail is nearly 4° from the projected radius vector at 60° from the head; it would seem that this formation must have been north of the orbital plane. Two fainter tails are nearly in the radius vector. On May 23d and the dates following up to June 3d there are strong streamers of different material from that which composed the tail before May 18th, apparently subject to a much higher acceleration. These are situated nearly in the projected radius vector, the rest of the tail lagging to the north, leaving these strong formations as the southern edge of the tail. The average lag of the tail at a point approximately 15,000,000 miles from the head on May 23d, 26th, 28th,

and 29th was 7,000,000 miles. Manifestly these preliminary values may be subject to considerable errors, though the agreement of the different values obtained is quite close.

6. Several of the photographs before May 18th indicate fainter streamers preceding the main tail and lying nearly in the prolonged radius vector. The faint southern branch seen on the morning of the 19th (civil date), nearly parallel to and only 5° north of the ecliptic, was probably such an advance formation. It is quite possible that such a streamer may have touched the Earth, probably between May 19.0 and May 19.5, but the Earth must have passed considerably to the south of the main portion of the tail.

Professor INNES' suggestion in *Transvaal Observatory Circular,* No. 3, that the tail would be repelled by the light reflected from the Earth has been offered independently in letters received at this and at other American observatories. While theoretically some such action is possible, only about one fourth of the Earth's surface would have acted upon the part of the comet observed; from our knowledge of the relative intensities of sunlight and moonlight it is difficult to conceive how such action could equal the one-hundred-thousandth part of that exerted by the Sun; it is, moreover, controverted by the lag of the tail *toward* the Earth after the transit of the head. That so small a force could overcome the relative orbital velocity of the particles of over forty miles per second, bring them to a stop, and drive them away, disrupting the tail, is difficult to conceive on any theory, either of light pressure or electrical action.

I have in hand the computation of the orbits and the acceleration of the moving masses observed in the tail. Prints or positives, preferably from plates taken with portrait lenses during the period from May 23d to June 10th, from observatories differing considerably in longitude from Mt. Hamilton would be of great assistance in this investigation. I should be glad to receive such prints or positives, particularly from the longitudes of Europe, Africa, Australia, and Hawaii, in exchange for positives from the Mt. Hamilton series.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1910.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

New Moon ...	July 6, $1^h 20^m$ P.M.	New Moon ...	Aug. 4, $10^h 37^m$ P.M.
First Quarter ..	" 14, 12 24 A.M.	First Quarter ..	" 12, 6 1 P.M.
Full Moon	" 22, 12 37 A.M.	Full Moon	" 20, 11 14 A.M.
Last Quarter ..	" 29, 1 34 A.M.	Last Quarter ..	" 27, 6 33 A.M.

The Earth is in aphelion or at greatest distance from the Sun on the morning of July 4th.

Mercury is a morning star on July 1st, having passed its greatest west elongation from the Sun on June 19th. It then rises about an hour and a quarter before sunrise and will be visible in the morning twilight under good weather conditions; but it is drawing nearer to the Sun and comes into conjunction with that body on the morning of July 19th. It then becomes an evening star and gradually moves out to eastern elongation, reaching this point on August 30th. The elongation 27° 14′ is much greater than the average, as it occurs only five days after aphelion, but the planet is 13° south of the Sun; so the interval between the setting of the Sun and of the planet is less than one hour, and it will hardly be possible to see the planet at this elongation. The latter half of the year is generally unfavorable for a view of the planet as an evening star, but affords the best opportunity for view as a morning star.

Venus is still a morning star, rising not quite two and one half hours before sunrise through July. During August the interval becomes less, being about one hour and fifty minutes at the end of the month. The maximum interval comes during the latter half of July. The apparent distance of the planet from the Sun diminishes continually during the two months, from 39° on July 1st to 21° on August 30th, but at the same time the greater southern motion of the Sun tends to increase the interval between the rising of the planet and of the Sun; and this partially counterbalances the diminution of the interval

caused by the approach of the planet to the Sun. So *Venus* remains in fair position for observation.

Mars is still an evening star and remains so throughout the two months' period, but is too near conjunction for easy observation. On July 1st it sets a little less than two hours after sunset, on August 1st only one hour after, and on August 31st not quite half an hour later. It is too near the Sun for naked-eye observations during the last few days of July and throughout August. It moves from *Cancer* through *Leo* 38° eastward and 13° southward. On August 3d it passes 40′ north of the first magnitude star *Alpha Leonis,* a distance about one third more than the apparent diameter of the Sun or Moon. As the star and planet on that date both set less than an hour after sunset, naked-eye view will hardly be possible. The planet reaches it maximum distance from the Sun on July 22d, but it will continue slowly to increase in distance from the Earth until nearly the middle of September. It is about at its minimum brightness, and will change very little in this respect for several months.

Jupiter remains an evening star in the southwestern sky. It sets shortly before midnight on July 1st and at about 8 P. M., an hour and one half after sunset, on August 31st. It can therefore be easily seen throughout the two months, although its duration of visibility to the naked eye toward the end of August will not be long. It moves 8° eastward and 4° southward in the constellation *Virgo,* and at the end of August is not far from the first magnitude star *Spica, Alpha Virginis.*

Saturn rises at about 1 A. M. on July 1st and shortly after 9 P. M. on August 31st, so it is getting into position for late evening observation. It moves very slowly eastward until August 20th in the constellation *Aries* and then begins to retrograde. As seen in the telescope, the rings are wider open than they were before conjunction, the minor axis being nearly one third of the major. When the rings are at their widest opening the minor axis is not quite one half of the major; this epoch will not be reached for several years.

Uranus comes to opposition with the Sun on July 16th, and is then above the horizon the entire night. At the end of August it sets at about half after one in the morning. It is

therefore in good position for observation throughout most of the night, and if any bright star were near it could be found with little difficulty on any clear moonless night; but, unfortunately, there are no bright stars near the planet to afford a means of easy identification. The planet is in *Sagittarius* east and north of the milk dipper group and moves about 2° northward during the two months.

Neptune comes to conjunction with the Sun on the night of July 11th, and is therefore not in good position for observation with a good telescope.

NOTES FROM PACIFIC COAST OBSERVATORIES.

VISUAL OBSERVATIONS OF HALLEY'S COMET, JANUARY-MAY, 1910.

A brief note in Number 129 of these *Publications* describes the visual observations of Halley's Comet which were made in December, 1909. Additional micrometric measures of the comet's position have been secured on the following dates: January 28th, 29th, February 11th, 28th, and March 11th, before conjunction with the Sun; May 5th and 15th, when the comet was a morning object; and May 20th, when the comet had once more passed to the east of the Sun. These measures were all made with the 12-inch telescope, and on March 11th and May 15th the hour-angle at the time of observation exceeded six hours.

The comet was first seen in the morning sky on the night of April 12th (morning of April 13th, civil time), when it was estimated to be of about the fifth magnitude, and had a well-defined nucleus of strong orange-yellow color and a faint bushy tail. After transiting the Sun, the comet was seen in the western sky on the evening of May 19th at about 7:30 P. S. T., and a good circle reading position was secured. On the following evening, May 20th, an accurate position observation was made by referring the comet to the 7.2 magnitude star A. G. Berlin A 1724. During the measures the comet moved from the north-preceding to the south-following side of the star, passing so close to it that at the instant of conjunction in right ascension the star and nucleus were separated by only about 6″. So far as could be determined by eye estimates, the star's brightness was not affected by this transit of the coma.

During the period of greatest brightness of the comet the instrumental equipment of the observatory was principally

devoted to securing as complete as possible a set of spectrographic, photographic, and polariscopic observations. The nucleus and coma were, however, examined visually with the 36-inch refractor on the nights of Tuesday, May 10th, and Friday, May 13th (astronomical dates; civil time, Wednesday and Saturday mornings, respectively), and with the 12-inch on the evening of May 20th. On May 10th the nucleus appeared as a small, round disk, ten settings of the micrometer, in various positions angles, giving a mean diameter of 2".6. On the north-following side (toward the Sun) were well-defined, quite bright envelopes, while on the south-preceding side was an equally well-defined parabolic-shaped shadow effect, the vertex being tangent to the nucleus, and the axis extending in the position angle 251°. The contrast in brightness on the two sides of the nucleus was so strong that it was difficult to realize that it was merely a contrast effect and not an actual shadow that was seen.

On May 13th the shadow effect was again seen, the axis lying in position-angle 281° (at 15^h 35^m P. S. T.), but instead of bright envelopes in front of the nucleus (toward the Sun), there were two bright wings, from 40" to 45" in length, extending from the nucleus in position-angles 251° and 322°, respectively. The south-preceding wing was the brighter, broader, and rather shorter of the two. These wings did not envelope the nucleus, but appeared to originate from the side of the nucleus away from the Sun, generally appearing tangent to it and at times almost detached from it. The seeing was only fair on both mornings.

On the evening of May 20th a bright envelope was seen on the side toward the Sun, and in front of, or outside of this, a secondary, much fainter envelope. Measures from the nucleus in the approximate axis of the tail gave the breadth of 73" to the inner envelope, while the outer edge of the secondary one lay fully 180" from the nucleus (at 8^h 24^m P. S. T.). In a line through the nucleus at right angles to the axis, the outer edges of the bright envelope lay about 4' from the nucleus, the south-following wing being somewhat brighter and broader than the other. The axis of the shadow-effect lay in position-angle 46°.

The short exposure photographs of the comet's head obtained with the Crossley reflector on these dates will afford data for a more accurate study of these phenomena.

Watch was kept by the writer of the appearance of the comet's tail in the morning sky up to and including Saturday morning, May 21st. The tail extended to the Milky Way in *Aquila* on several mornings, but on no occasion could I see it beyond the Milky Way. On the morning of the 18th it was very bright, on the morning of the 19th the axis lay somewhat farther to the north, and the tail was fainter, though still very prominent, and to the south of it could faintly be seen the cone of the zodiacal light. On the morning of the 20th (civil time) the tail was still visible, being roughly about one third as bright as on the preceding day, but still distinctly brighter than the zodiacal light. It could readily be followed from the horizon to the Milky Way. On the morning of the 21st, however, no trace of it could be seen, though careful watch was kept from the time the Moon entered the deep haze on the western horizon until the Milky Way faded in the dawn. On the evening of the 19th of May a faint orange glow in the western sky, extending for a short distance from the position of the comet's head away from the Sun, marked the position of the comet's tail, and on the 20th, in spite of the bright moonlight, the tail could be traced distinctly for fully ten degrees.

R. G. AITKEN.

June 2, 1910.

SPECTROGRAPHIC ORBIT OF β *CAPRICORNI*.

The orbit of the spectroscopic binary β *Capricorni* ($\alpha = 20^h\ 15^m.4$, $\delta = -15°\ 5'$) has been computed from plates obtained at the Lick Observatory with the Mills three-prism spectrograph and 36-inch equatorial.

The spectrum is given as composite in the Harvard classification, but only the brighter component is recorded on these plates. It is approximately solar type. Forty-five observations were used.

The preliminary elements were found by plotting the observations, reduced to one cycle, and applying well-known graphical methods. They were corrected by trial and error. The

system is interesting because of its long period and large (projected) semi-major axis.

The elements are as follows:—

$$V = 1375.3 \text{ days}$$
$$T = \text{J. D. } 2416035$$
$$v = -18.8^{\text{km}} \text{ per second}$$
$$e = 0.44$$
$$\omega = 124^\circ.0$$
$$K = 22.2^{\text{km}} \text{ per second}$$
$$a \sin i = 377{,}000{,}000^{\text{km}}$$

PAUL W. MERRILL.

MT. HAMILTON, CAL.

DOUBLE-STAR NOTES.

Misure di Stelle dopic . . . negli anni 1886-1900 da G. V. SCHIAPARELLI.[1]—The most important recent contribution to the literature of double-star astronomy is the second volume of SCHIAPARELLI'S double-star measures, containing the results of 7,177 measures of 636 systems made with the 18-inch[2] Merz-Repsold refractor of the Milan Observatory in the fifteen years 1886-1900. The earlier volume, of which the author modestly says this is a continuation, was published in 1888, and contained 3,781 measures of 465 systems, the fruit of eleven years' work (1875-1885) with the 8-inch Merz refractor of the same observatory. This simple statement is sufficient to show that few astronomers have made larger contributions to this department of the science, and examination of the new volume will convince anyone that size is in this case a correct indication of value. The observing list was prepared with care, including mainly the more important double stars in the Dorpat and Pulkova catalogues (Σ and OΣ stars), with shorter lists from the discoveries of BURNHAM and HOUGH and a few miscellaneous pairs. Every precaution was taken to avoid or minimize the systematic and accidental errors of observation. In all cases in which the stars were known to be in orbital motion, the measures were repeated year after

[1] The death of this great astronomer on July 4, 1910, is reported in the newspapers.

[2] The Milan refractor is usually referred to as an 18-inch telescope; but the unit is the French inch. In English inches the aperture is 19.17 (= 487mm).

year, in some cases for the whole quarter-century. For many of the most interesting binaries we have therefore an almost continuous record of the motion for this length of time in the work of a single observer. Such measures are the most valuable of contributions to the study of double-star astronomy.

The brief introduction to the volume gives an interesting description of the great Milan equatorial, the location, mounting, object-glass, and micrometer, the conditions under which the measures were made, the observing methods followed, and the arrangement adopted in publication. That the telescope is an excellent one, and that the atmospheric conditions at Milan are good, is amply shown, as SCHIAPARELLI hopes it may be, by the measures in this volume. Important as these two items are, however, they only afford the medium through which the skillful observer works, and they acquire their value only through being used by him.

SCHIAPARELLI remarks that his experience in the study of *Mars* "has demonstrated in the most incontestible manner that even in the midst of a great city one has intervals of quiet atmosphere, such as permit the most exquisite definition and, when there is sufficient light, the most perfect images." It is of interest, too, to read that his experience proved to him that no noticeable improvement was effected by cutting down the aperture by diaphragms of different sizes. "Therefore," he says, "in all of my observations I have always used the full aperture."

Observations of Southern Double Stars.—Under this heading Mr. R. T. A. INNES publishes in Transvaal Observatory Circular No. 1 a list of 268 new double stars discovered with the 9-inch Grubb refractor at Johannesburg. A second table is also included in the circular, containing notes, estimates of position-angles and distances, etc., of known double stars which are in motion or which are misidentified in published catalogues.

The new double stars are numbered in continuation of those published by the same observer in the *Monthly Notices, R. A. S.*, for December, 1903, and bring the total of his discoveries to 700. Only five of the new pairs have distances estimated to exceed 5″, and 74 are estimated to fall within the limit of 2″. Unfortunately, the 9-inch telescope is not yet provided with a

micrometer, so that both angles and distances had to be estimated.

In his introduction Mr. INNES says that the search for new pairs has been confined to the sky area south of — 19° declination, and that only stars "easily seen in the 2-inch finder undergo scrutiny in the 9-inch, and it is believed that this limits the examination to stars of the 8.8 magnitude or brighter." The present writer hopes that Mr. INNES may later decide to extend his survey to include stars of 9.0 magnitude and to take such precautions as will enable him to state definitely that he has examined all stars to a given magnitude in a given region of the sky. My experience in similar work in the northern sky leads me to believe that this can only be done by preparing charts in advance, which shall contain all of the stars to be examined. With all possible care on the observer's part, it is still practically inevitable that some stars brighter than the limits set will escape examination unless such a plan is followed. The charts have the further advantages that they serve as a record of the work done, enable the observer to say on what date and under what conditions a given star was examined, make the identification of any double star easy and certain, not only at the time of first examination but whenever it is desired to remeasure it, and, most important of all, furnish accurate data for statistical studies.

Mr. INNES is at present the only observer in the southern hemisphere who is engaged in double-star work, and everyone who is interested in this department of astronomy will wish him continued success. It is a pleasure to be able to say that his instrumental equipment is soon to be greatly increased.

Micrometric Measures of Double Stars, by PHILIP FOX.—It will be recalled that Professor PHILIP FOX, of the Yerkes Observatory, last year succeeded to the directorship of the Dearborn Observatory. It is gratifying to find that Mr. FOX intends to devote at least a portion of his time with the 18½-inch refractor to the continuation of double-star measures. The paper noted above appears in No. 611 of the *Astronomical Journal*, and contains measures made with the 12- and 40-inch refractors of the Yerkes Observatory, as well as some with the Dearborn telescope.

Sutton Double-Star Observations. — Under this title the veteran observer, Dr. W. DOBERCK, publishes in *Astronomische Nachrichten,* Nos. 4394-95, a continuation of his long series of double-star measures. Dr. DOBERCK is also continuing his investigations of orbits, as appears from two papers published in *Astronomische Nachrichten,* No. 4400, entitled "Synopsis of Elements of Orbits of Some Double Stars," and "On the Orbit of 40 o^2 *Eridani.*" It is to be hoped that Dr. DOBERCK will soon publish in collected form the results of his extensive investigations in this field.

Among other recent papers of interest to double-star observers we note the publication in *Astronomische Nachrichten,* No. 4406, of a list of eighty-two new double stars by M. ROBERT JONCKHEERE, of the observatory at Hem, France. The stars for the most part, are fainter than 9.0 B. D. magnitude, though several of the later discoveries are brighter than this. It is a satisfaction to note that M. JONCKHEERE has apparently set himself rigorous limits in defining a double star. With one exception, the measured distances are less than 4″, and more than half are less than 2″.

Attention should also be called to a very interesting theoretical paper by Mr. H. C. PLUMMER, entitled "On the Analytical Method of Finding the Orbit of a Double Star," which is published in the *Observatory* for May, 1910. In this paper Mr. PLUMMER derives relations between the coefficients of the equation of the apparent ellipse and the geometrical elements of the true orbit, which are, in effect, equivalent to those employed in the well-known KOWALSKY method, though by no means identical. Mr. PLUMMER notes that his method has "points of contact with known graphical methods," and, incidentally, directs attention to a convenient and accurate graphical method published by him in Volume LX (page 483) of the *Monthly Notices, R. A. S.* R. G. AITKEN.

June 14, 1910.

NOTE ON THE DOUBLE STAR OΣ 251.

The double star OΣ 251 was examined with the 36-inch telescope on the night of June 2, 1909, and found to be a close, unequal pair. No further measures were obtained until recently,

when the earlier observation was confirmed on two nights. March 5 and May 27, 1910. The three measures give:—

1909.420	5°.3	0″.21	1 night
1910.288	14 .0	0 .22	2 nights

As the two components differ a full magnitude in brightness, there is no question as to the correctness of the quadrant.

HUSSEY, in his catalogue of the Otto Struve stars, and BURNHAM, in his General Catalogue, pronounced this star probably single, as it had not been seen double in any large telescope except on one night in 1875, when HALL and HOLDEN, using the Washington 26-inch, suspected elongation in 70° or 80°. BURNHAM failed to see it double with the 18½-inch telescope in 1879, as did SCHIAPARELLI, in Milan, in 1881, 1888, 1889, and 1890. In 1898 and 1899 it was examined by HUSSEY and myself with the 36-inch under excellent conditions and showed no evidence of duplicity. The early measures by OTTO STRUVE, from 1843 to 1853, gave discordant angles ranging from 105° to 152°.

In view of these observations, positive and negative, there seems to be no doubt of the fact that OΣ 251 is a binary star in comparatively rapid orbital motion. It would certainly have been seen double in 1899 if the components then had been as well separated as they are now.[1] R. G. AITKEN.

June 9, 1910.

THE AQUARID METEORS.

On the morning of May 4th, while working at the Crossley dome, quite a number of meteors were seen in the southeast by both Dr. CURTIS and myself. Remembering that the η Aquarid meteors, to which most of these obviously belonged, came to a maximum about this date and were supposed to be connected with Halley's Comet, I began to plot the paths of all seen. As a consequence, a good radiant was secured from six meteors, all quite well plotted. Observations on May 5th failed to supply more than two meteors that were certainly members of the stream. On May 11th, however, another

[1] OΣ 251 is B_0 D. + 32°.2250, 7.9 magnitude. B_0 D. + 32°.2252, 7.4 magnitude, is 56s following and 2′ north. It is, of course, possible that the latter star was examined on some occasions instead of the right star.

radiant in *Aquarius* was secured from six meteors. Observations on May 13th again failed to supply more than one or possibly two Aquarids. None were seen May 18th, though carefully looked for.

The parabolic elements for May 4th and May 11th were calculated and are tabulated below, with the corresponding elements for Comet Halley:—

	G.M.T.	α	δ	i	q	Ω	π	π-Ω
Comet Halley,				163° 12′	0.5869	57° 16′	168° 58′	111° 42′
Aquarids,	May 4.97	334°.0	—3°.4	166 15	0.6770	44 4	156 6	112 2
Aquarids,	" 11.99	342 .0	—0 .6	166 41	0.6297	50 51	155 7	104 16

The close resemblance of the elements leaves no reasonable doubt that these meteors were intimately connected with the comet in time past and that they are now moving in nearly identical orbits.

It is a matter of interest to notice the decided eastward shift of the radiant between the two dates and also to mention that May 6th seems the latest date on which these meteors were ever before observed. CHAS. P. OLIVIER.

CLASSIFICATION OF THE HYDROGEN ($H\alpha$) FLOCCULI.

The prime characteristic of the hydrozen flocculi, as photographed with the $H\alpha$ line, is their tendency to assume regular and distinctive structural forms. While these forms vary widely in character, three principal types, designated provisionally *unipolar, bipolar,* and *multipolar,* may be recognized as follows:—

Unipolar, usually surrounding single (or close double) sunspots, but sometimes found where no spot is present; the form resembles that of a simple vortex, either right-handed or left-handed.[1]

Bipolar, usually associated with two spots of opposite polarity, which are in most cases at opposite ends of a spot-group. Sometimes one or both of the spots may be absent, or replaced by a bright flocculus. The flocculi closely resemble the lines of force uniting the north and south poles of a bar magnet. Many variations of this structure occur, usually in connection

[1] For examples of this type, see *Nature*, **82**, 23. Fig. 4. November. 1909.

with the presence in the group of small spots or eruptive flocculi. This type is a very common one. In fact, the two spots at the opposite ends of a group are almost invariably found to be of opposite polarity, accompanied by $H\alpha$ flocculi showing this structure. Moreover, photographs of the flocculi made with the hydrogen lines $H\beta$, $H\gamma$ and $H\delta$ bring out the general features of the type (though less clearly than $H\alpha$), so that the resemblance to lines of force was detected in my earliest photographs of the hydrogen flocculi, made with $H\beta$ and $H\gamma$ in 1903. Even the H_2 and K_2 flocculi and the faculæ in direct photographs, show a similar structure.

Multipolar, usually surrounding groups containing several spots, and sometimes persisting after the spots have disappeared. The disturbed area, frequently of enormous extent, is roughly elliptical in form, with long, curved flocculi, of peculiar structure, directed toward the interior. Generally the major axis of the ellipse is nearly parallel to the long axis of the spot group. An excellent example may be found in my paper on "Solar Vortices." [1]

Sometimes the multipolar type is associated with, or hardly distinguishable from the bipolar, and both multipolar and bipolar flocculi have been found with flocculi of the unipolar type. In spite of this fact, and the obvious necessity of providing for subdivisions of the above types, the distinction between the unipolar, bipolar, and multipolar forms will be readily recognized in examining a long series of good photographs of the Sun made with $H\alpha$.

In addition to the above types, the dark *filaments* and the bright eruptions must of course find a place in a general classification of the hydrogen flocculi. GEORGE E. HALE.

A RADIAL VELOCITY OF COMET *a* 1910.

It is only very rarely that an accurate radial velocity of a comet can be obtained by means of the spectrograph, for two reasons: few comets are sufficiently bright to permit the use of high dispersion, and there must be present in the comet spectrum lines whose wave-lengths are accurately known.

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[1] *Astrophysical Journal,* **28**, Plate VI, September, 1908.

Comet *a* 1910 offered such an opportunity, for it was bright, and the well-known D-lines, due to sodium, were present as emission lines.[1]

On January 27 the D-lines were photographed with a grating spectrograph attached to the 36-inch refractor. The second order was employed, and a sodium flame was used as the source of the comparison spectrum. Both D_1 and D_2 of the comet spectrum are recorded on the plate. D_2 shows considerable strength, and can be measured quite accurately, while D_1, being very faint, is difficult to see under the microscope, and its measured displacement must consequently be given small weight. The radial velocity referred to the center of the Earth, as obtained from the measures of D_2, was $+ 63.3^{km}$. (D_1 gave $+ 77.4^{km}$. It is so faint and difficult of measurement that it was given only one-fourth weight.) This displacement was assumed to be due mostly to the radial velocity of the comet with respect to the Earth, though it was thought possible that a minor part of it might be due to other causes, as for example an initial velocity of ejection of the sodium vapor from the nucleus. From elements of the comet by KOBOLD (in *Astronomische Nachrichten*, 4385) the computed radial velocity relative to the Earth for the date of observation was found to be $+ 62.7^{km}$. The agreement of the computed velocity with the value obtained from the measures of D_2 shows that the displacement of the sodium lines was due practically entirely to the former cause.

The only previous radial velocity determinations of comets of which I have been able to find a record were visual determinations made by estimating the displacements of the bright D-lines in the spectrum of the great comet of September, 1882, by MM. THOLLON and GOUY, and at Lord CRAWFORD'S Observatory.[2]

In this connection it may be of interest to note the practical possibility of utilizing radial velocity determinations in the computation of the preliminary orbit of a bright comet. The approximate readings of the circles of the telescope would give

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[1] *Lick Observatory Bulletin*, No. 174.

[2] *Observatory*, **6**, 94, 1883.

the data which are necessary to refer the velocities to the Sun, and would also give a rough orientation of the orbit. Such an orbit, however, would not be comparable in accuracy to an orbit computed from accurate observations of position. MOULTON[1] has developed a method for the determination of a parabolic orbit from two observations of apparent position, and one of the motion in the line of sight. The difficulty of obtaining accurate positions of this comet during the first week after announcement of its discovery indicates that radial velocities might find a useful practical application on rare occasions like the present one. The D-lines were sufficiently intense in the comet's spectrum to warrant the belief that it would have been entirely possible, weather permitting, to have photographed them with high dispersion in broad daylight on the first few days after the discovery of the comet. S. ALBRECHT.

April, 1910.

ASYMMETRICAL LINES IN SUN-SPOT SPECTRA.

In a note on the classification of the lines in sun-spot spectra, which appeared in the last number of these *Publications,* I omitted to mention the asymmetrical lines, which promise to be of great interest when additional laboratory data become available for purposes of comparison. Some remarkable cases of asymmetry not at first supposed to be such because of their wide departure from the normal type, have recently been detected. Extensive investigations on the Zeeman effect for chromium, nickel, and other elements, upon which Dr. KING and Mr. BABCOCK are now engaged, will soon show the behavior of these lines in the laboratory.

In addition to the triplets and quadruplets mentioned in the same note, lines split by the magnetic field into a greater number of components undoubtedly appear in sun-spot spectra, though they are not resolved on our present photographs.

GEORGE E. HALE.

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[1] *Astrophysical Journal,* **10,** 14, 1899.

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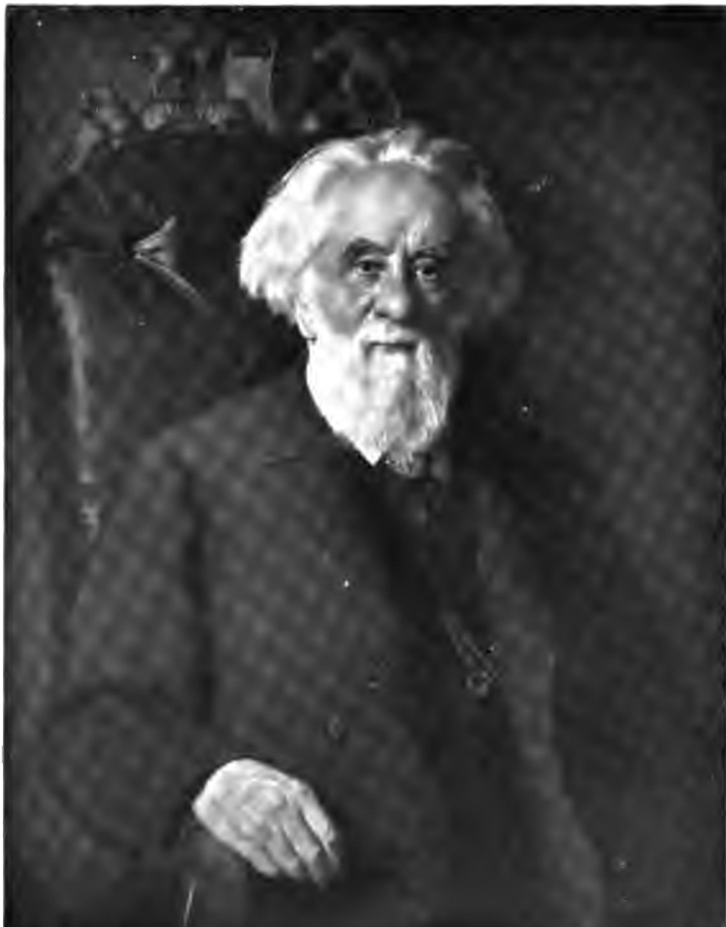

SIR WILLIAM HUGGINS.

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SIR WILLIAM HUGGINS, K. C. B., O. M.

BY W. W. CAMPBELL.

The name of Sir WILLIAM HUGGINS is intimately associated with the entire history of astronomical spectroscopy. With RUTHERFURD, SECCHI, ÅNGSTRÖM, DRAPER, and others, he was a pioneer in this subject; and by virtue of long life, enthusiasm, and uncommon wisdom, his contributions have enriched astronomical knowledge during a full half century. His lamented death on May 12, 1910, at the ripe age of eighty-six years, calls for a review of his remarkable career.

WILLIAM HUGGINS was born in London on February 7, 1824. His father was in commercial life, and was able to provide the son not only with a good education, but the financial means to follow astronomy in a private capacity, unattached to university or established observatory. His early education was received in the City of London School, and he later studied the languages, mathematics, and various branches of science extensively under private tutors. Astronomy and microscopy were subjects of special interest, and it was a difficult question with him as to which he should attempt to advance through original investigations. The decision was made in favor of astronomy. In 1856 he removed to 90 Upper Tulse Hill, then a short distance in the open country south of London, now within the great city, where he erected an observatory in connection with his dwelling-house; and there all of his work was done. "It consisted of a dome twelve feet in diameter and a transit-room. There was erected in it an equatorially mounted telescope by DOLLAND of five inches

aperture, at that time looked upon as a large rather than a small instrument." He commenced work on the usual lines, taking transits, observing, and making drawings of planets. In 1858 the 5-inch refractor was replaced by a Clark 8-inch refractor of great excellence.

In the *Nineteenth Century Review* for June, 1897, Sir WILLIAM has given an interesting account of his entry into the spectroscopic field:—

"I soon became a little dissatisfied with the routine character of ordinary astronomical work, and in a vague way sought about in my mind for the possibility of research upon the heavens in a new direction or by new methods. It was just at this time, when a vague longing after newer methods of observation for attacking many of the problems of the heavenly bodies filled my mind, that the news reached me of KIRCHHOFF's great discovery of the true nature and the chemical constitution of the Sun from his interpretation of the Fraunhofer lines.

"This news was to me like the coming upon a spring of water in a dry and thirsty land. Here at last presented itself the very order of work for which in an indefinite way I was looking,—namely, to extend his novel methods of research upon the Sun to the other heavenly bodies. A feeling as of inspiration seized me. I felt as if I had it now in my power to lift a veil which had never before been lifted; as if a key had been put into my hands which would unlock a door which had been regarded as forever closed to man—the veil and door behind which lay the unknown mystery of the true nature of the heavenly bodies. This was especially work for which I was to a great extent prepared, from being already familiar with the chief methods of chemical and physical research.

It was just at this time that I happened to meet at a soirée of the Pharmaceutical Society, where spectroscopes were shown my friend and neighbor, Dr. W. ALLEN MILLER, professor of chemistry at King's College, who had already worked much on chemical spectroscopy. A sudden impulse seized me to suggest to him that we should return home together. On our way home I told him of what was in my mind, and asked him to join me in the attempt I was about to make, to apply KIRCHHOFF's methods to the stars. At first, from consideration of the

great relative faintness of the stars, and the great delicacy of the work from the Earth's motion, even with the aid of a clockwork, he hesitated as to the probability of our success. Finally he agreed to come to my observatory on the first fine evening for some preliminary experiments as to what we might expect to do upon the stars.

" . . . From the Sun, with which the Heidelberg professors had to do,—which, even bright as it is, for some parts of the spectrum has no light to spare,—to the brightest stars is a very far cry. The light received at the Earth from a first magnitude star, as *Vega*, is only about the one-forty-thousand-millionth part of that received from the Sun.

"Fortunately, as the stars are too far off to show a true disk, it is possible to concentrate all the light received from the star upon a large mirror or object-glass, into the telescopic image, and so increase its brightness.

"We could not make use of the easy method adopted by FRAUNHOFER of placing a prism before the object-glass, for we needed a terrestrial spectrum, taken under the same conditions, for the interpretation, by a simultaneous comparison with it of the star's spectrum. KIRCHHOFF's method required that the image of a star should be thrown upon a narrow slit simultaneously with the light from a flame or from an electric spark.

"These conditions made it necessary to attach a spectroscope to the eye end of the telescope, so that it would be carried with it, with its slit in the focal plane. Then, by means of a small reflecting prism placed before one half of the slit, light from a terrestrial source at the side of the telescope could be sent into the instrument, together with the star's light, and so form a spectrum by the side of the stellar spectrum, for convenient comparison with it.

"This was not all. As the telescopic image of a star is a point, its spectrum will be a narrow line of light without appreciable breadth. Now for the observation either of dark or of bright lines across the spectrum a certain breadth is absolutely needful. To get breadth, the point-like image of the star must be broadened out.

"As light is of first importance, it was desirable to broaden the star's image only in the one direction necessary to give breadth to the spectrum; or, in other words, to convert the

stellar point into a short line of light. Such an enlargement in one direction only could be given by the device, first employed by FRAUNHOFER himself, of a lens convex or concave in one direction only, and flat, and so having no action on the light, in a direction at right angles to the former one. . . .

"It is scarcely possible at the present day, when all these points are as familiar as household words, for any astronomer to realize the large amount of time and labor which had to be devoted to the successful construction of the first star spectroscope. Especially was it difficult to provide for the satisfactory introduction of the light for the comparison spectrum. We soon found, to our dismay, how easily the comparison lines might become instrumentally shifted, and so be no longer strictly fiducial. As a test we used the solar lines as reflected to us from the Moon—a test of more than sufficient delicacy with the resolving power at our command.

"Then it was that an astronomical observatory began, for the first time, to take on the appearance of a laboratory. Primary batteries, giving forth noxious gases, were arranged outside one of the windows; a large induction coil stood mounted on a stand on wheels so as to follow the positions of the eye end of the telescope, together with a battery of several Leyden jars; shelves with Bunsen burners, vacuum tubes, and bottles of chemicals, especially of specimens of pure metals, lined its walls.

"In 1870 my observatory was enlarged from a dome of twelve feet in diameter to a drum having a diameter of eighteen feet. This alteration had been made for the reception of a larger telescope made by Sir HOWARD GRUBB, at the expense of a legacy to the Royal Society, and which was placed in my hands on loan by that society. This instrument was furnished with two telescopes: an achromatic of fifteen inches aperture and a Cassegrain of eighteen inches aperture, with mirrors of speculum metal. At this time one only of these telescopes could be in use at a time. Later on, in 1882, by a device which occurred to me of giving each telescope an independent declination axis, the one working within the other, both telescopes could remain together on the equatorial mounting, and be equally ready for use.

" . . . It is not easy for men of the present generation,

familiar with the knowledge which the new methods of research of which I am about to speak have revealed to us, to put themselves back a generation, into the position of the scientific thought which existed on these subjects in the early years of the Queen's reign. At that time any knowledge of the chemical nature and of the physics of the heavenly bodies was regarded as not only impossible of attainment by any method of direct observation, but as, indeed, lying altogether outside the limitations imposed upon man by his senses, and by the fixity of his position upon the Earth.

"It could never be, it was confidently thought, more than a matter of presumption, whether even the matter of the Sun, and much less that of the stars, were of the same nature as that of the Earth, and the unceasing energy radiated from it due to such matter at a high temperature. The nebular hypothesis of LAPLACE at the end of the last century required, indeed, that matter similar to that of the Earth should exist throughout the solar system; but then this hypothesis itself needed for its full confirmation the independent and direct observation that the solar matter was terrestrial in its nature. This theoretical probability in the case of the Sun vanished almost into thin air when the attempt was made to extend it to the stellar hosts; for it might well be urged that in those immensely distant regions an original difference of the primordial stuff as well as other conditions of condensation were present, giving rise to groups of substances which have but little analogy with those of our earthly chemistry. . . .

"The dark lines were described first by WOLLASTON in 1792, who strangely associated them with the boundaries of the spectral colors, and so turned contemporary thought away from the direction in which lay their true significance. It was left to FRAUNHOFER in 1815, by whose name the dark lines are still known, not only to map some six hundred of them, but also to discover similar lines, but differently arranged, in several stars. Further, he found that a pair of dark lines in the solar spectrum appeared to correspond in their position in the spectrum, and in their distance from each other, to a pair of bright lines which were nearly always present in terrestrial flames. This last observation contained the key to the interpretation of the dark lines as a code of symbols, but FRAUN-

HOFER failed to use it; and the birth of astrophysics was delayed. An observation by FORBES at the eclipse of 1836 led thought away from the suggestive experiments of FRAUNHOFER; so that in the very year of the Queen's accession the knowledge of the time had to be summed up by Mrs. SOMERVILLE in the negation: 'We are still ignorant of the cause of these rayless bands.'

"Later on, the revelation came more or less fully to many minds. FOUCAULT, BALFOUR STEWART, ÅNGSTRÖM prepared the way. Prophetic guesses were made by STOKES and by Lord KELVIN. But it was KIRCHHOFF who, in 1859, first fully developed the true significance of the dark lines; and by his joint work with Bunsen on the solar spectrum proved beyond all question that the dark lines in the spectrum of the Sun are produced by the absorption of the vapors of the same substances, which when suitably heated give out corresponding bright lines; and, further, that many of the solar absorbing vapors are those of substances found upon the Earth. The new astronomy was born.

"Soon after the close of 1862, in collaboration with Dr. W. A. MILLER, I sent a preliminary note to the Royal Society, 'On the Lines of Some of the Fixed Stars,' in which we gave diagrams of the spectra of *Sirius, Betelgeux*, and *Aldebaran*, with the statement that we had observed the spectra of some forty stars, and also the spectra of the planets *Jupiter* and *Mars*. It was a little remarkable that on the same day on which our paper was to be read, but some little time after it had been sent in, news arrived there from America that similar observations on some of the stars had been made by Mr. RUTHERFURD. A very little later similar work on the spectra of the stars was undertaken in Rome by SECCHI and in Germany by VOGEL.

"In February, 1863, the strictly astronomical character of the observatory was further encroached upon by the erection, in one corner, of a small photographic tent furnished with baths and other appliances for the wet collodion process. We obtained photographs, indeed, of the spectra of *Sirius* and *Capella;* but from want of steadiness and more perfect adjustment of the instruments, the spectra, though defined at the edges, did not show the dark lines as we expected. The

dry collodion plates then available were not rapid enough; and the wet process was so inconvenient for long exposures, from irregular drying, and draining back from the positions in which the plates had often to be put, that we did not persevere in our attempts to photograph the stellar spectra. I resumed them with success in 1875, as we shall see further on.

"Whenever the nights were fine, our work on the spectra of the stars went on, and the results were communicated to the Royal Society in April, 1864; after which Dr. MILLER had not sufficient leisure to continue working with me.

" . . . I pass on at once, therefore, to the year 1876, in which by the aid of the new dry plates, with gelatine films, introduced by Mr. KENNETT, I was able to take up again, and this time with success, the photography of the spectra of the stars, of my early attempts at which I have already spoken.

"By this time I had the great happiness of having secured an able and enthusiastic assistant by my marriage in 1875.

"The great and notable advances in astronomical methods and discoveries by means of photography, since 1875, are due almost entirely to the great advantages which the gelatine dry plate possesses for use in the observatory, over the process of DAGUERRE, and even over that of wet collodion. The silver-bromide gelatine plate, which I was the first, I believe, to use for photographing the spectra of stars, except for its grained texture, meets the need of the astronomer at all points. This plate possesses extreme sensitiveness; it is always ready for use; it can be placed in any position; it can be exposed for hours; lastly, immediate development is not necessary, and for this reason, as I soon found to be necessary in this climate, it can be exposed again to the same object on succeeding nights; and so make up by successive instalments, as the weather may permit, the total long exposure which may be needful.

"The power of the eye falls off as the spectrum extends beyond the blue, and soon fails altogether. There is therefore no drawback to the use of glass for the prisms and lenses of a visual spectroscope. But while the sensitiveness of a photographic plate is not similarly limited, glass, like the eye, is imperfectly transparent, and soon becomes opaque, to the parts of the spectrum at a short distance beyond the limit of the

visible spectrum. To obtain, therefore, upon the plate a spectrum complete at the blue end of stellar light, it was necessary to avoid glass, and to employ instead Iceland spar and rock crystal, which are transparent up to the limit of the ultra-violet light which can reach us through our atmosphere. Such a spectroscope was constructed and fixed with its slit at the focus of the great speculum of the Cassegrain telescope.

"How was the image of a star to be easily brought, and then kept, for an hour, or even for many hours, precisely at one place on a slit so narrow as about the one two-hundredth of an inch? For this purpose the very convenient device was adopted of making the slit-plates of highly polished metal, so as to form a divided mirror, in which the reflected image of a star could be observed from the eye end of the telescope by means of a small telescope fixed within the central hole of the great mirror. A photograph of the spectrum of *a Lyræ*, taken with this instrument, was shown at the Royal Society in 1876.

"In the spectra of such stars as *Sirius* and *Vega*, there came out in the ultra-violet region, which up to that time had remained unexplored, the completion of a grand rhythmical group of strong dark lines, of which the well-known hydrogen lines in the visible region form the lower members. Terrestrial chemistry became enriched with a more complete knowledge of the spectrum of hydrogen from the stars. Shortly afterwards, CORNU succeeded in photographing a similar spectrum in his laboratory from earthly hydrogen."

The years 1863 to 1890 were made fruitful by HUGGINS, especially in the comparison of terrestrial and stellar spectra. He established that the principal elements in the Earth's surface strata exist also in the atmospheres of the stars in the form of vapors and gases. Other studies attempted to arrange the principal stars in the order of their evolutionary history—in the order of their effective ages—from the different appearances of the hydrogen and metallic lines in their spectra.

HUGGINS's observation of the spectrum of a nebula, for the first time in 1864, has probably never been surpassed in dramatic interest in any department of science. From the days of Sir WILLIAM HERSCHEL it had been a much-discussed question whether the nebulæ—the faintly shining bodies which had not been resolved into separate star-images—were con-

tinuous in structure like a great gaseous cloud, or were composed of stars unresolvable on account of their enormous distances. To let HUGGINS speak:—

"The nature of these mysterious bodies was still an unread riddle. Towards the end of the last century the elder HERSCHEL, from his observations at Slough, came very near suggesting what is doubtless the true nature, and place in the cosmos, of the nebulæ. I will let him speak in his own words:—

"'A shining fluid of a nature unknown to us.

"'What a field of novelty is here opened to our conceptions! . . . We may now explain that very extensive nebulosity, expanded over more than sixty degrees of the heavens, about the constellation of *Orion;* a luminous matter accounting much better for it than clustering stars at a distance. . . .

"'If this matter is self-luminous, it seems more fit to produce a star by its condensation than to depend on the star for its existence.'

"This view of the nebulæ as parts of a fiery mist out of which the heavens had been slowly fashioned, began, a little before the middle of the present century, at least in many minds, to give way before the revelations of the giant telescopes which had come into use, and especially of the telescope, six feet in diameter, constructed by the late Earl of ROSSE at a cost of not less than £12,000.

"Nebula after nebula yielded, being resolved apparently into innumerable stars, as the optical power was increased; and so the opinion began to gain ground that all nebulæ may be capable of resolution into stars. According to this view, nebulæ would have to be regarded, not as early stages of an evolutional progress, but rather as stellar galaxies already formed, external to our system — cosmical 'sandheaps' — too remote to be separated into their component stars. Lord ROSSE himself was careful to point out that it would be unsafe from his observations to conclude that all nebulosity is but the glare of stars too remote to be resolved by our instruments. In 1858 HERBERT SPENCER showed clearly that, notwithstanding the Parsonstown revelations, the evidence from the observation of nebulæ up to that time was really in favor of their being early stages of an evolutional progression.

"On the evening of August 29, 1864, I directed my telescope for the first time to a planetary nebula in *Draco*. The reader

may now be able to picture to himself to some extent the feeling of excited suspense, mingled with a degree of awe, with which, after a few minutes of hesitation, I put my eye to the spectroscope. Was I not about to look into a secret place of creation?

"I looked into the spectroscope. No spectrum such as I expected! A single bright line only! At first I suspected some displacement of the prism, and that I was looking at a reflection of the illuminated slit from one of its faces. This thought was scarcely more than momentary. Then the true interpretation flashed upon me. The light of the nebula was monochromatic, and so, unlike any other light I had as yet subjected to prismatic examination, could not be extended out to form a complete spectrum. After passing through the two prisms it remained concentrated into a single bright line, having a width corresponding to the width of the slit, and occupying in the instrument a position at that part of the spectrum to which its light belongs in refrangibility. A little closer looking showed two other bright lines on the side towards the blue, all the three lines being separated by intervals relatively dark.

"The riddle of the nebulæ was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas. Stars after the order of our own Sun, and of the brighter stars, would give a different spectrum; the light of this nebula had clearly been emitted by a luminous gas. With an excess of caution, at the moment I did not venture to go further than to point out that we had here to do with bodies of an order quite different from that of the stars. Further observations soon convinced me that, though the short span of human life is far too minute relatively to cosmical events for us to expect to see in succession any distinct step in so august a process, the probability is indeed overwhelming in favor of an evolution in the past, and still going on, of the heavenly hosts. A time surely existed when the matter now condensed into the Sun and planets filled the whole space occupied by the solar system, in the condition of gas, which then appeared as a glowing nebula, after the order, it may be, of some now existing in the heavens. There remained no room for doubt that the nebulæ, which our telescopes revealed to us, are the early stages of long processions of

cosmical events, which correspond broadly to those required by the nebular hypothesis in one or other of its forms."

Further observations identified two of the lines as due to hydrogen. Observations by various spectroscopists have increased the number of bright lines known to exist in nebular spectra to thirty or forty, but aside from hydrogen and helium, accounting for about one half of all the observed lines, the constitution of the so-called gaseous nebulæ is unknown.

To leave the subject of the nebular spectrum here would mislead the inexperienced, and it is necessary to say that only a minority of the nebulæ thus far observed in this way show spectra consisting chiefly of bright lines. The spiral nebulæ have spectra chiefly continuous, and their composition and physical state remain a mystery. Even so for bright-line nebulæ, as observed by HUGGINS in 1864, we cannot say that they are shining by virtue of the heat of incandescence; the tendency of present-day opinion is that their substances are comparatively cool, and that their luminosity must arise from other conditions not now understood with certainty.

Important contributions to our knowledge of temporary stars —the so-called new stars—were made by HUGGINS in half a dozen papers on their spectra. The principal stars studied were those which appeared suddenly in *Corona Borealis*, in the Great Nebula in *Andromedæ*, and in *Auriga*.

HUGGINS was among the first to apply the spectroscope to the study of comets. A dozen papers by him, on cometary spectra, make interesting reading, for they record the gradual evolution of our knowledge of physical conditions existing in comets up to the year 1882. For example, speaking of observations of Winnecke's Comet of 1868 made on the evening of June 22d, he says:—

"When a spectroscope furnished with two prisms of 60° was applied to the telescope, the light of the comet was resolved into three very broad, bright bands. . . .

"In the two more refrangible of these bands the light was brightest at the less refrangible end, and gradually diminished towards the other limit of the bands. This gradation of light was not uniform in the middle and brightest band, which continued of nearly equal brilliancy for about one-third of its

breadth from the less refrangible end. This band appeared to be commenced at its brightest side by a bright line.

"The least refrangible of the three bands did not exhibit a similar marked gradation of brightness. This band, though of nearly uniform brilliancy throughout, was perhaps brightest about the middle of its breadth. . . .

"The following day I carefully considered these observations of the comet with the hope of a possible identification of its spectrum with that of some terrestrial substance. The spectrum of the comet appeared to me to resemble some of the forms of the spectrum of carbon which I had observed and carefully measured in 1864. On comparing the spectrum of the comet with the diagrams of these spectra of carbon, I was much interested to perceive that the positions of the bands in the spectrum, as well as their general characters and relative brightness, agreed exactly with the spectrum of carbon when the spark is taken in olefiant gas. . . .

"It was with the spectrum of carbon, as thus obtained, that the spectrum of the comet appeared to agree. It seemed, therefore, to be of much importance that the spectrum of the spark in olefiant gas should be compared directly in the spectroscope with the spectrum of the comet. The comparison of the gas with the comet was made the same evening, June 23d. . . .

"The brightest end of the middle band of the cometic spectrum was seen to be coincident with the commencement of the corresponding band in the spectrum of the spark. As this limit of the band was well defined in both spectra, the coincidence could be satisfactorily observed up to the power of the spectroscope; and may be considered to be determined within about the distance which separates the components of the double line D. As the limits of the other bands were less distinctly seen, the same amount of certainty of exact coincidence could not be obtained. We considered these bands to agree precisely in position with the bands corresponding to them in the spectrum of the spark.

"The apparent identity of the spectrum of the comet with that of carbon rests not only on the coincidence of position in the spectrum of the bands, but also upon the very remarkable resemblance of the corresponding bands in their general characters and in their relative brightness. This is very noticeable

in the middle band, where the gradation of brightness is not uniform. This band in both spectra remained of nearly equal brightness for the same proportion of its length.

"On a subsequent evening, June 25th, I repeated these comparisons, when the former observations were fully confirmed in every particular. On this evening I compared the brightest band with that of carbon in the larger spectroscope, which gives a dispersion of about five prisms.

"The remarkably close resemblance of the spectrum of the comet to the spectrum of carbon necessarily suggests the identity of the substances by which in both cases the light was emitted."

The application of the Doppler-Fizeau principle to the measurement of stellar velocities has assumed great importance in astronomical investigation. It is now easy to look backward and say that this importance was inevitable, but it was not easy, half a century ago, to look forward and say that this must be so. It is characteristic of the pioneers in this field that they were slow to publish their ideas and observations.

It was FIZEAU, in 1848, who first enunciated the principle correctly that motions of approach and recession must cause corresponding shiftings of the entire spectrum, including the dark lines of FRAUNHOFER, toward the violet and red, respectively, but without change of color. He also outlined methods for applying the principle to measuring the motions of celestial bodies toward and away from the observer. While these methods were sound theoretically, they were unpractical. All matters spectroscopic were then mysterious, and FIZEAU'S statements attracted no serious attention. In fact, his lecture on the subject in 1848, before a minor society in Paris, was not published until 1869. The subject was given early consideration by HUGGINS and MILLER, but publication was delayed until 1868, when the following statement was issued:

"In a paper 'On the Spectra of Some of the Fixed Stars' by myself and Dr. W. A. MILLER, Treas. R. S., we gave an account of the method by which we had succeeded during the years 1862 and 1863 in making trustworthy simultaneous comparisons of the bright lines of terrestrial substances with the dark lines in the spectra of some of the fixed stars. We were at the time fully aware that these direct comparisons were not

only of value for the more immediate purpose for which they had been undertaken, namely, to obtain information of the chemical constitution of the investing atmospheres of the stars, but that they might also possibly serve to tell us something of the motions of the stars relatively to our system. If the stars were moving towards or from the Earth, their motion, compounded with the Earth's motion, would alter to an observer on the Earth the refrangibility of the light emitted by them, and consequently the lines of terrestrial substances would no longer coincide in position in the spectrum with the dark lines produced by the absorption of the vapors of the same substances existing in the stars."

Repeated efforts to measure the velocities of recession and approach of the stars were made in later years by HUGGINS and other observers; and while their results were inaccurate and erroneous, they did not work entirely in vain, for the successes of the later observers in any subject are built, to some extent, upon the failures of the pioneers. We now know that visual methods could not have had more than very moderate success, even under the most favorable conditions. The coming of very sensitive dry-plates has made it possible for a 6-inch telescope and spectrograph to measure the velocities of a greater number of stars than could be done with the 36-inch telescope, using visual methods of spectroscopy.

Perhaps HUGGINS's greatest contributions to the development of celestial spectroscopy have come from his efforts to interpret the original observations by means of laboratory observations made by himself and others. To these problems he brought philosophic judgment of unusual breadth and depth. His public addresses, reviewing astronomical progress and forecasting the problems of the future, were of unusual interest and excellence. The Cardiff address of 1891 was notable in this regard.

The epoch-making work of Huggins brought him early and full recognition from universities and learned societies. His government alone was slow to reward him. He was Rede Lecturer in Cambridge University in 1869; he received the degree of LL. D. from Cambridge in 1870, and the degree of D. C. L. from Oxford in 1870. He was made a member of the Royal Society in 1865. He received the Lalande Gold

Medal and the Janssen Gold Medal of the Paris Academy of Sciences; the Gold Medal of the Royal Astronomical Society; the Royal, the Rumford, and the Copley medals of the Royal Society; the Bruce Medal of the Astronomical Society of the Pacific; and perhaps others.

He received honorary degrees from many universities, and was elected to membership in the leading academies. He was president of the British Association in 1891, the year of the Cardiff meetings. He was president of the Royal Society during the years 1900-05. On the occasion of the Diamond Jubilee of Queen VICTORIA, in his seventy-fourth year, he was knighted; and in his seventy-eighth year he received appointment to the Order of Merit.

It is the way of Nature that ripeness must give way to youth. Fortunately, the example and work of such as HUGGINS live on into succeeding generations, and the history of astronomy will keep his name on the list of great pioneers.

For thirty-five years he experienced able and devoted support in his scientific duties and undertakings from Lady HUGGINS, whose assistance was always real and active. The history of science does not tell us of more devoted co-workers than Sir WILLIAM and Lady HUGGINS. The sympathies of all who have had the good fortune to know them go to her who has been left behind.

GIOVANNI VIRGINIO SCHIAPARELLI.

By R. G. Aitken.

Three times within as many years we have had to record the death of one of those leaders in astronomical science upon whom our Society had bestowed the highest honor within its gift, the Bruce Medal; and it is now our sad duty to add another name to this roll—Giovanni Virginio Schiaparelli, who died on July 4, 1910, in the seventy-sixth year of his age.

It is not necessary here to pass in review the rich contributions Schiaparelli made to the progress of his chosen science, for, in March, 1902,[1] the President of our Society, in announcing the award of the Bruce Medal, gave a full account of his great services.

Fortunately, Schiaparelli's activities did not cease with his withdrawal from the directorship of the Milan Observatory in 1900. Ill health and failing eyesight, he might well have pleaded, absolved him from further labors; but, notwithstanding these afflictions, he continued his work to the end of his life. In 1903 his book, "Astronomy in the Old Testament," was published; in 1908, papers in *Scientia,* a quarterly review, on the birth and progress of astronomy amongst the Babylonians; in 1909, the volume containing his measures of double-stars in the years 1886 to 1900[2]; and in the present year, in the *Bulletin Astronomique* a paper expressing his matured views on cometary orbits, cosmic currents, and meteorites. The mere mention of these works is sufficient to show Schiaparelli's working power and the wide range of his interests.

In 1908, Professor E. C. Pickering made a study of the "Foreign Associates of National Societies,"[3] in which he showed that a man's status as foreign associate in the national societies of the seven great nations of the world (Russia, United States, Germany, Austria, Great Britain, France, and Italy) might fairly be taken as a measure of his eminence. Judged by this standard, Schiaparelli stood in the very front rank of the scientific men of the world, for he was honored by

[1] See these *Publications,* **14,** 37, 1902.
[2] Reviewed on page 137 of the present volume of these *Publications.*
[3] *Popular Science Monthly,* **73,** 372, 1908

GIOVANI VIRGINIO SCHIAPARELLI.

five of these societies (in addition, of course, to his own national society, the Royal Academy of the Lincei), our own country being the only one that failed to recognize him in this manner. Four national societies (those of Russia, Prussia, Austria, and France) "confer a special honor on a few of their foreign associates by granting them the privileges of resident members, or by placing them in a special class of honorary members." No scientific man has been thus honored by all four societies, and only two, SUEAS and SCHIAPARELLI, by three of them.

Thus it appears that, like his great contemporary, NEWCOMB, his worth was fully recognized by his own generation, and that, like NEWCOMB again, he had the privilege of continuing his chosen work to the very end of a long life.

AN EXPEDITION TO PHOTOGRAPH A COMET.

By FERDINAND ELLERMAN.

The Comet Committee of the Astronomical and Astrophysical Society of America, having secured a grant from the Rumford Fund of the National Academy of Sciences in the fall of 1909, decided to send an expedition to the mid-Pacific for photographing Halley's Comet, provided suitable apparatus and an observer could be borrowed, as the funds were not sufficient to pay for much more than the expenses of the expedition.

The location decided on by the committee was the island of Oahu of the Hawaiian group, and it fell to my lot to be chosen to carry out the program. A leave of absence covering the time required for the expedition was granted by the president of the Carnegie Institution.

The various parts of the instrumental equipment were assembled at the work-shops of the Mt. Wilson Solar Observatory in Pasadena, and put into working condition. They were just ready when Comet *a* 1910 made its appearance, and were sent to Mt. Wilson and given a try-out. Everything worked satis-

factorily; the instruments were sent to Pasadena, repacked, and shipped on to Honolulu.

The equipment consisted of the following:

A 6.4-inch Warner and Swasey equatorial mounting with driving clock complete and 6.4-inch Clark objective were loaned by the Lick Observatory. (The iron column of the mounting was not used, but in place of it two cement piers, fastened together with planks and iron plates, supported the head of the mounting.)

A 6-inch portrait lens of thirty-two inches focus was loaned by the John A. Brashear Company and mounted in a metal camera built for the society. The camera was fastened to the telescope tube by wooden blocks and iron straps.

A Tessar lens of 2¼ inches aperture and 9⅞ inches focus, loaned by the Bausch & Lomb Optical Company, was mounted on a wooden camera and used on 8 x 10 plates. This wooden box was mounted on top of the metal camera in such a manner that it could be pointed in any direction, and in photographing the comet was pointed so that the entire tail would fall on the plate except when the tail exceeded fifty degrees.

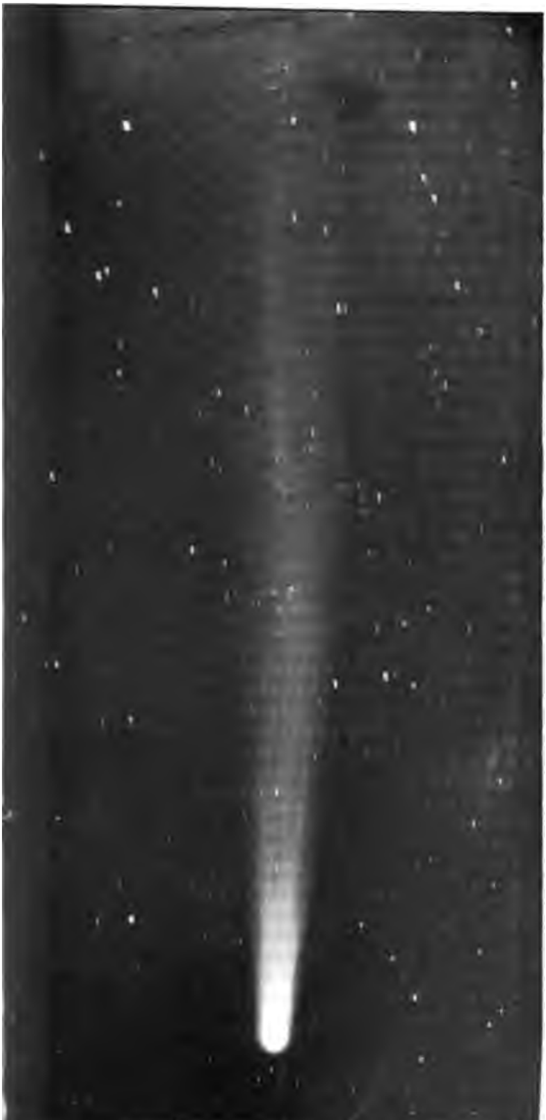
An eyepiece with cross-hairs and electric illumination for guiding completed the outfit.

Leaving San Francisco on March 22d, we arrived at Honolulu on the 28th, with the sky looking very bad. Heavy clouds hung over the mountains, while the upper sky was covered with a thick haze. Several days were spent in investigating local weather conditions and looking up probable sites. In this I was assisted by the local Weather Bureau and some of the staff of the College of Hawaii.

The climatic conditions vary a great deal on the islands, and one can find almost any climate to suit the work required. The region near the ocean on the lee or southwest side of the island is dry and the percentage of clear sky high, but as one goes nearer the mountains and into higher land one encounters more and more cloudiness and rain. A distance of four or five miles makes a great difference in the conditions.

The coral plain lying southwest from Pearl Harbor has a large percentage of clear skies and little rainfall and seemed a favorable location, but for the work on Halley's Comet, where a clear eastern sky reaching down to the horizon was desirable,

OBSERVING STATION, NEAR HONOLULU.



HALLEY'S COMET, HONOLULU STATION.

6-inch Brashear portrait lens.

May 8, 1910.

$2^h\ 2^m$ to $2^h\ 54^m$ G. M. T.

May 10, 1910.

$2^h\ 17^m$ to $2^h\ 58^m$ G. M. T.

it was found that the clouds which continually hung over the mountains north of Honolulu would greatly interfere, as they came right in line of the comet. A site south and east of Honolulu was therefore considered, and it was found that at Diamond Head a clear eastern horizon was obtainable, and a site was selected on the south slope about 150 feet above the ocean and 300 feet back from it. A splendid road circles Diamond Head and made the site easily accessible from Honolulu. The electric cars run to the base of the slopes of the crater and within about a mile of the shelter, but as the cars stop running at midnight I made the trips from Honolulu at night on a motorcycle, which I found very practical, as the roads around the city in general were splendid.

There was no running water to be had, however, so the plates were taken to the cottage I had rented, and all the dark-room and laboratory work was done in the bathroom, which was transformed for this purpose. The water supply of Honolulu comes from the streams in the mountains and answers very well for all photographic purposes.

The shelter, whose co-ordinates were $\lambda = 157° 48'.5$, $\phi = +21° 15'.5$, was constructed of a frame-work of pine, well braced to withstand the wind, and covered with canvas. A partition divided the observing-room, which was about nine feet square, from the darkened room for changing plates. The roof was mounted on castors and rolled back to the north, giving a free sweep of the sky.

The weather during the greater portion of April was very unfavorable. While very little rain fell at Diamond Head, the clouds were dense. The comet was first sighted on April 14th and 15th, but only a few minutes' exposure obtained. There were no observations till the 25th on account of clouds. From about the 25th, to the 17th of May, the sky was good most of the mornings and a good set of photographs was obtained. There were, however, some clouds, especially low down, which interfered every morning and covered the head of the comet until it was from 5° to 12° high.

On May 18th the sky was cloudy till about 3 P. M., when the clouds began to disperse, and by 3:30 was perfectly clear until 6 o'clock (G. M. T. 14^h to $16^h 30^m$). The definition of the Sun most of the time was good and the granulation came

out very distinct, but no trace of the comet in transit was detected or suspected. Clouds on the nights of May 17th, 18th, and 19th prevented visual observations of the tail.

From May 21st to June 1st few photographs were obtained, but in June, up to the 11th, a fairly complete series was secured. At the latter date observations were discontinued.

The comet was observed photographically on thirty-six different dates, and fifty-nine exposures were made with the 6-inch Brashear lens and eleven exposures with the Tessar. More exposures would have been made with the short camera had it not been for the violent gusts of the trade wind which was blowing strong most of the time, and the position of the camera-box gave great purchase and caused much shaking of the telescope.

While the weather was far from ideal for astronomical photography, it seems to have been a great deal better than in the eastern part of the United States, and as a good collection of photographs of the comet was obtained the result of the expedition must be considered very satisfactory.

THE FOURTH CONFERENCE OF THE INTERNATIONAL UNION FOR CO-OPERATION IN SOLAR RESEARCH.

By H. C. Wilson.

This conference, held at the Mount Wilson Solar Observatory from August 29th to September 3d, 1910, was remarkable for the number and representative character of the delegates in attendance. Thirteen different countries and fifty different observatories and laboratories, where work is carried on in connection with the study of the Sun, were represented. The following is the official list of the members of the conference:—

Mr. Charles G. Abbot,	Smithsonian Astrophysical Observatory,	Washington, D. C.
Mr. Walter S. Adams,	Mt. Wilson Solar Observatory.	
Prof. J. S. Ames,	Johns Hopkins University,	Baltimore, Md.
Mr. Harold D. Babcock,	Mt. Wilson Solar Observatory.	
Prof. J. O. Backlund,	Observatoire de Poulkovo,	Poulkovo, Russia.
Prof. E. E. Barnard,	Yerkes Observatory,	Williams Bay, Wis.
Prof. A. Belopolsky,	Observatoire de Poulkovo,	Poulkovo, Russia.
M. Jean Bosler,	Observatoire de Meudon,	Meudon, France.
Prof. F. P. Brackett,	Pomona College,	Claremont, Cal.
Miss Cora G. Burwell,	Mt. Wilson Solar Observatory.	
Prof. W. W. Campbell,	Lick Observatory,	Mount Hamilton, Cal.
Prof. C. A. Chant,	University of Toronto,	Toronto, Canada.
M. Henri Chretien,	Observatoire de Nice,	Nice, France.
Rev. P. R. Cirera, S. J.,	Observatorio del Ebro,	Tortosa, Spain.
Dr. W. W. Coblentz,	Bureau of Standards,	Washington, D. C.
Rev. A. L. Cortie, S. J.,	Stonyhurst College Observatory,	Lancashire, England.
M. A. Cotton,	Ecole Normale Superieure,	Paris, France.
M. H. Deslandres,	Observatoire de Meudon,	Meudon, France.
Prof. N. Donitch,	Observatoire de l'Universite,	St. Petersburg, Russia.
Mr. Frank L. Drew,	Mt. Wilson Solar Observatory.	
Prof. F. W. Dyson,	Royal Observatory,	Edinburgh, Scotland.
Mr. Ferdinand Ellerman,	Mt. Wilson Solar Observatory.	
Dr. P. Eversheim,	University of Bonn,	Bonn, Germany.
Prof. Charles Fabry,	Universite de Marseilles,	Marseilles, France.
Dr. Edward A. Fath,	Mt. Wilson Solar Observatory.	
Mrs. W. P. Fleming,	Harvard College Observatory,	Cambridge, Mass.
Mr. F. E. Fowle,	Smithsonian Astrophysical Observatory,	Washington, D. C.
Prof. A. Fowler,	Imperial College of Science and Technology,	South Kensington, London, England.
Prof. Philip Fox,	Dearborn Observatory,	Evanston, Ill.
Prof. E. B. Frost,	Yerkes Observatory,	Williams Bay, Wis.
Dr. Henry G. Gale,	University of Chicago,	Chicago, Ill.
Prof. L. H. Gilmore,	Throop Polytechnic Institute,	Pasadena, Cal.
Miss Clementina D. Griffin,	Mt. Wilson Solar Observatory.	

Prof. GEORGE E. HALE,	Mt. Wilson Solar Observatory.	
M. M. HAMY,	Observatoire de Paris,	Paris, France.
Prof. J. HARTMANN,	Koenigliche Sternwarte,	Goettingen, Germany.
Prof. K. HAUSSMANN,	Technische Hochschule,	Aachen, Germany.
Prof. J. v. HEPPERGER,	Imperial Observatory,	Vienna, Austria.
Major E. H. HILLS,	33 Prince's Garden,	London, England.
Prof. W. J. HUMPHREYS,	U. S. Weather Bureau,	Washington, D. C.
M. IDRAC,	Observatoire de Meudon,	Meudon, France.
Prof. J. C. KAPTEYN,	Astronomical Laboratory,	Groningen, Holland.
Prof. H. KAYSER,	University of Bonn,	Bonn, Germany.
Dr. ARTHUR S. KING,	Mt. Wilson Solar Observatory.	
Prof. H. KONEN,	Physikalisches Institut,	Muenster, Germany.
Prof. F. KUESTNER,	Koenigliche Sternwarte,	Bonn, Germany.
Mr. C. O. LAMPLAND,	Lowell Observatory,	Flagstaff, Ariz.
Sir JOSEPH LARMOR,	Royal Society,	London, England.
Miss Jennie B. LASBY,	Mt. Wilson Solar Observatory.	
Prof. A. O. LEUSCHNER,	University of California,	Berkeley, Cal.
Prof. H. C. LORD,	Emerson McMillin Observatory,	Columbus, Ohio.
Dr. JAMES D. MADDRILL,	International Latitude Observatory,	Ukiah, Cal.
Prof. A. G. MCADIE,	U. S. Weather Bureau,	San Francisco, Cal.
Prof. E. MILLER,	University of Kansas,	Lawrence, Kan.
Dr. WALTER M. MITCHELL,	Detroit Observatory,	Ann Arbor, Mich.
Prof. H. F. NEWALL,	University Observatory,	Cambridge, England.
Mr. F. G. PEASE,	Mt. Wilson Solar Observatory.	
Prof. E. C. PICKERING,	Harvard College Observatory,	Cambridge, Mass.
J. S. PLASKETT, Esq.,	Dominion Observatory,	Ottawa, Canada.
Comte A. DE LA BAUME PLUVINEL,	7 Rue de la Baume,	Paris, France.
Prof. E. PRINGSHEIM,	University of Breslau,	Breslau, Germany.
Prof. P. PUISEUX,	Observatoire de Paris,	Paris, France.
Prof. A. RICCO,	Osservatorio astrofisico,	Catania, Sicily.
Prof. G. W. RITCHEY,	Mt. Wilson Solar Observatory.	
Prof. A. L. ROTCH,	Blue Hill Observatory,	Hyde Park, Mass.
Dr. HENRY NORRIS RUSSELL,	Princeton University,	Princeton, N. J.
Prof. J. R. RYDBERG,	University of Lund,	Lund, Sweden.
Dr. CHARLES E. ST. JOHN,	Mt. Wilson Solar Observatory.	
Prof. FERNANDO SANFORD,	Leland Stanford Jr. University,	Palo Alto, Cal.
Dr. FRANK SCHLESINGER,	Allegheny Observatory,	Allegheny, Pa.
Prof. ARTHUR SCHUSTER,	Victoria Park,	Manchester, England.
Prof. K. SCHWARZSCHILD,	Astrophysikalisches Observatorium,	Potsdam, Germany.
Prof. F. H. SEARES,	Mt. Wilson Solar Observatory.	
Dr. V. M. SLIPHER,	Lowell Observatory,	Flagstaff, Ariz.
Prof. FREDERICK SLOCUM,	Yerkes Observatory,	Williams Bay, Wis.
Miss RUTH E. SMITH,	Mt. Wilson Solar Observatory.	
Prof. S. W. STRATTON,	Bureau of Standards,	Washington, D. C.
Prof. H. STRUVE,	Koenigliche Sternwarte,	Berlin, Germany.
Prof. W. L. TOWER,	University of Chicago,	Chicago, Ill.
Prof. S. D. TOWNLEY,	Leland Stanford Jr. University,	Palo Alto, Cal.
Prof. H. H. TURNER,	University Observatory,	Oxford, England.
Miss LOUISE WARE,	Mt. Wilson Solar Observatory.	
Miss PHŒBE WATERMAN,	Mt. Wilson Solar Observatory.	
Prof. F. R. WATSON,	University of Illinois,	Champaign, Ill.
Prof. H. C. WILSON,	Goodsell Observatory,	Northfield, Minn.
Prof. A. WOLFER,	Sternwarte des Eidgenossischen Polytechnikums,	Zurich, Switzerland.

The members gathered at the headquarters, the Hotel Maryland, in Pasadena, California, on Sunday afternoon and Monday morning. The first day was spent in examining the Pasadena offices, machine- and instruments-shops, and physical laboratory of the Solar Observatory. From four to six in the afternoon a garden party was given at the home of Dr. and Mrs. HALE. Tuesday was occupied by the ascent of the mountain, which was accomplished in various ways by the different members—in carriages, on foot, and by saddle-horse.

All the formal sessions were held at the summit of Mount Wilson, in the museum, a one-story wooden building, with a second roof of white canvas, which kept the building quite cool and comfortable even in the hottest part of the day.

The first session was called to order at 9:30 A. M. on Wednesday by Professor ARTHUR SCHUSTER, chairman of the Executive Committee. Professor E. C. PICKERING was chosen as presiding officer for the first day, Professor W. W. CAMPBELL for Thursday, and Professor E. B. FROST for Friday. Messrs. WALTER S. ADAMS of the Solar Observatory, P. PUISEUX of Paris, H. KONEN of Muenster, and HAROLD D. BABCOCK of the Solar Observatory were elected secretaries of the conference.

Professor GEO. E. HALE gave the address of welcome. He said that the most important work of the Union was the stimulation of research, and the meetings at Oxford and Paris had been of use in this way. It was a question, perhaps, whether formal co-operation would be a success. One thing which had been accomplished was the establishment of secondary standards of wave-length. He spoke of the need for tertiary standards, and said that the spectrograms taken with the tower telescope were well adapted to the measurement of such standards. For the study of the spectra of sun-spots and the Zeeman effect a map of the spot spectrum is required on a large scale. Dr. HALE suggested one centimeter to one Ångström unit, and asked the question whether a map on such a scale could be prepared and what would be the practicable length of the sections of the map. He spoke of the tower telescope and said that it was designed especially to meet the conditions on Mount Wilson. It might not be adapted to use in other localities. The arrangement of the collimating lens, grating, and mirrors at the bottom of the 80-foot well and of

the slit and plateholder at the surface was described with the aid of diagrams rapidly sketched on the blackboard.

Photographs of the Sun can be obtained from both edges of the Hα (red hydrogen) line simultaneously by using two mirrors and two slits. Such photographs often differ very much from each other, the one showing the effect of descending, the other, of ascending, currents of hydrogen.

In the spectra of sun-spots certain lines are double and others are triple. The same lines are always affected in the same way in different spots. The iron line at λ 6303 is triple, sometimes wide, sometimes less separated. To show this requires high resolving power and extremely high dispersion. Experiments in the laboratory show that doubling, tripling, and even higher multiplication of metallic lines is produced by passing the light through a powerful electro-magnetic field. In a spot spectrum the components of some lines may be parallel and those of others may be convergent at the same time, showing differences of the electric field at different levels. It is possible from these differences to determine the direction of the axis of a vortex about a sun-spot.

Professor HALE explained a device by means of which, with several slits close together, he photographs the spectra of different portions of the same spot on the same plate at once, and thus is enabled to determine the direction of the lines of force around the spot.

In conclusion, he said that work with the Hα line was much more important than with the calcium lines for the study of eruptive phenomena.

The report of the Executive Committee was then given by Professor SCHUSTER, and the report of the committee on wave-lengths by Professor KAYSER. The latter report was perhaps the most important of those made at the conference, in that it presented for adoption a table of 371 standard wave-lengths, mostly of the iron arc spectrum. This table will be published in the October number of the *Astrophysical Journal*. Professor KAYSER spoke of the fact that MICHELSON'S determination, by the interferometer method, of the wave-length of the red Cadmium line at λ 6438 had been adopted at a former conference as the primary standard. Progress has been made on the wave-lengths of iron by Messrs. FABRY and BUISSON at Paris,

EVERSHEIM at Bonn, and PFUND at the Johns Hopkins University. The results obtained by these three agree very closely, the differences from the mean of the three rarely amounting to more than .002 or .003 of an Ångström unit.

The following recommendations presented by the committee were adopted after a short debate and after each recommendation had been read in turn in English, French, and German:—

RECOMMENDATIONS OF THE COMMITTEE ON WAVE-LENGTHS.

1. In the region of the spectrum in which three independent measurements by the interferometer method of the lines of the iron arc are available, i. e. between λ 4282 and λ 6494, the arithmetical mean of the three measurements shall be adopted as definite international standards of second order, provided there is sufficient agreement between them.

2. The committee to be given authority to publish these standards as soon as possible.

3. For the part of the spectrum in the neighborhood of λ 5800, where the number and character of the iron lines are not satisfactory, the committee proposes the use of barium lines as additional standards.

4. Laboratories or observatories possessing first-rate concave gratings are invited to determine by interpolation as soon as possible standards of the third order in the spectrum of the iron arc within the above region (i. e. λ 4282 to λ 6494).

5. The measurement of standards of the second order shall be extended to shorter and longer wave-lengths, and the arithmetical mean of three independent determinations shall be adopted as secondary standards.

6. Standards of the third order shall then be obtained in the manner indicated.

7. The above system of standards shall be called the International System, the unit on which it is based being called the International unit (I. A.), as defined by the conference of 1907.

8. It is desirable that in different laboratories possessing concave gratings of the first quality photographs of arc, spark, and solar spectra, and new measurements according to the international system shall be taken as soon as possible.

On Wednesday evening an address was given by Mr. C. G. ABBOT, director of the Smithsonian Astrophysical Observatory, in which he gave a brief historical outline of the study of solar radiation. The most probable value of the solar constant of radiation appears now to be about 1.92 calories per square centimeter per minute. From the last few years work at the Smithsonian Observatory at Washington and Mount Wilson, there are fairly strong indications of frequent variability of

the order of five or ten per cent in the intensity of the solar radiation outside the Earth's atmosphere, and there are also indications from the study of a longer interval that there is a periodic variation coinciding in time with that of sun-spot frequency, the maximum radiation accompanying the sun-spot minimum.

At the second session, Thursday morning, invitations were extended to the members of the conference to visit Lick Observatory, Leland Stanford Jr. University, and the University of California.

The report on the measurement of solar radiation was presented by Mr. C. G. ABBOT. As the committee had held no meeting, there being only two of the members present, the report could not be considered an official report of the committee, but it was accepted for record.

Professor FOWLER spoke of the fact that papers and photographs forwarded by Professor CALLENDAR had failed to arrive.

Professor HUMPHREYS described a new type of pyrheliometer designed by Mr. MARVIN of the Weather Bureau. It is of the electrical resistance type, the principal part being a coil of very thin nickel ribbon. Its resistance is independent of the portion of the coil upon which the heat falls. Several such instruments are now in use and the results are entirely in accord with those obtained by the Abbot secondary pyrheliometer.

Professor SCHWARZSCHILD spoke of the work of Messrs. MÜLLER and KRON at Alta Vista, on the peak of Mount Teneriffe. Their results agree exceedingly well with those of Mr. ABBOT.

Professor SCHUSTER said that it was desirable to study the variation of intensity of the solar radiation from different parts of the disk. The photosphere and absorbing layer are not separate and the effect from the two is not the same near the limb as near the center of the disk. One problem can be treated mathematically and that is where the heat is given out by radiation only—neglecting convection. On this supposition, calculating the absorption of air which we should expect if there were no other agency than pure air, the result for the solar radiation agrees with that obtained by ABBOT.

Professor PICKERING spoke of the possibility of observations of solar radiation being made at Arequipa if instruments could be furnished, and offered the use of the Harvard station and observers for that purpose.

In reply to the question whether a pyrheliometer of approved type would be sufficient for this work or would bolometric observations be required, Mr. ABBOT said that either many pyrheliometers might be employed at different stations or there should be at least one bolometric station aside from that of the Smithsonian Observatory. If any one would guarantee him $4,000 a year he would go to southern Mexico and make the observations.

Professor FOWLER presented the report of the committee on sun-spot observations, showing that six observers are now co-operating in the work of obtaining observations of spot spectra. One notable result is that the spot spectrum is found to be as constant as the Fraunhofer spectrum. Its study is therefore less interesting than was expected. The following resolutions were presented and adopted:—

1. That the reports of the Solar Committee and of the co-operating observers be printed in the *Transactions* of the Union in full or in abstract as circumstances may determine.

2. That notwithstanding the photographic results, visual observations are desirable and the committee should be continued.

3. That the committee be requested to prepare and circulate a revised scheme of observations.

4. In view of the fact that several observers have prepared catalogues of great numbers of sun-spot lines, it is desirable that these results be collated.

5. It is desirable that the sections of the new map of the sun-spot spectrum do not exceed sixty centimeters in length and be on a scale of five millimeters to one Ångström.

Professor NEWALL spoke of the possibility of using plane gratings for measuring wave-lengths of tertiary standard lines.

Mr. ADAMS spoke of the use of plane gratings in measuring solar rotation at Mount Wilson, and said that for a long distance in the spectrum the reduction factors follow a straight line. Experience shows that the results are extremely accurate, the accidental errors for the arc lines averaging only 0.0014 Ångström units and for the enhanced lines in the solar spectrum only 0.0020 Å.

Professor FABRY said that for short spaces of the spectrum plane gratings may be even better than concave gratings.

Dr. ST. JOHN emphasized the accuracy obtained with plane gratings, for short distances with sufficient standards between.

The report of the eclipse committee, in the absence of the chairman, Sir NORMAN LOCKYER, was presented by the secretary, Count A. DE LA BAUME PLUVINEL.

Some little debate occurred over the one recommendation of the committee, that angles of position around the Sun's limb be recorded from north toward east, but the recommendation was finally adopted.

Major HILLS spoke of the abvisability of the committee keeping in close touch with other committees in regard to preparations for observing eclipses.

Professor DONITCH spoke of the desirability of co-operation in observations of the chromospheric spectrum.

Professor CAMPBELL described a method of using a moving plateholder for photographing the flash spectrum, as applied by him in recent eclipses.

On Thursday evening Professor KAPTEYN gave an extremely interesting address on "Star Streams," of which it is impossible to give any adequate account here, but which will be published in full in the *Transactions* of the Solar Union.

From a study of the proper motions, according to Boss's catalogue, of the stars of the *Orion* or *B* spectral type he found that all of these stars in a large region of the sky, containing the constellations *Scorpio* and *Centaurus*, were moving in nearly the same direction and at nearly the same rate. This region covers 4,500 square degrees, extending roughly from $12^h\,0^m$ to $18^h\,0^m$ in right ascension and from $0°$ to $-60°$ in declination. In another region, of 1,300 square degrees around the constellation *Perseus*, from $2^h\,50^m$ to $4^h\,30^m$ in right ascension and from $+15°$ to $+55°$ in declination, all the stars of the same type were found to be moving in a different direction. Professor KAPTEYN finds that these apparent motions may be explained on the supposition of two star streams moving in exactly opposite directions at equal rates, their apparent motions being the resultants of their real motions combined with that of the Sun, so that the average apparent velocity in the line of sight of the stars of one group comes out about

twenty-eight kilometers per second, while that of the other is about eighteen kilometers. Professor KAPTEYN said that he was led to take up this investigation by finding a discrepancy of about nine kilometers in the velocity of the solar system as determined from the known radial velocities of the *Orion* type stars near the apex of the solar motion and from those near the antapex or opposite point of the heavens. He finds that these stars are very distant from the Sun, the theoretical parallax ranging from $0''.006$ to $0''.026$. On examining the proper motions of stars of other spectral types in the same regions of the sky, he finds that all of those which possess similar motions are of the *A* type, which is next in order of probable development to the *B* type.

At the third session, Friday morning, the report of the committee on the determination of solar rotation by the displacement of lines was presented by Mr. ADAMS. A resolution offered by Professor NEWALL was adopted, that the committee be reappointed with power to initiate and continue the plan of co-operation proposed at its first meeting.

M. DESLANDRES proposed to add to the field of work of the committee the study of the movements of the solar atmosphere, and therefore to change the name of the committee to that of "the committee on the study of solar motions," but this did not find favor.

Mr. ABBOT suggested that, as the lines of heavy elements disappear at the Sun's limb, measures of these lines might be taken at such distances from the limb as are practicable.

M. DESLANDRES reported on the work of M. PEROT of Meudon, and advocated the method of photographing the surface of the Sun in sections in the light of one particular portion of the spectrum. This method has the advantage that the edges of the limiting slit near the photographic plate serve as reference lines for measuring relative radial velocities all over the solar disk. The limiting slit may be one or two millimeters wide, with a particular line (*K* for instance) in the middle of the slit.

The report of the committee on the spectroheliograph was presented by Professor FROST in the absence of Professor HALE. It included a report from Father CIRERA of Tortosa, Spain, on the classification of faculæ; a report from Professor

Ricco of Catania, Sicily, showing that since 1908 the photosphere has been photographed on 418 days and the chromosphere on 366 days; and a report from Yerkes Observatory of over four thousand plates obtained with the spectroheliograph since 1904.

The resolutions offered by the committee and adopted by the conference were in substance as follows:—

1. That daily photographs of calcium flocculi be continued.
2. That provision be made for the measurement of the photographs.
3. That the Japanese Government be approached in regard to the establishment of a solar observatory in Japan.
4. That the observatories of Tacubaya, Mexico, and Madrid, Spain, be added to the list of co-operating observatories.
5. That the committee recognize the advisability of the use of spectroheliographs of high dispersion.
6. That the fund raised in Italy as a memorial of Father Secchi be devoted to the construction of a tower telescope.

On Friday afternoon the question as to whether the Solar Union should take up the study of stellar spectra was made the special topic of the first hour. Although there appeared to be general hesitation to make a definite proposition, it was soon found from an informal discussion that all were agreed upon the subject and it was formally voted—

That the Solar Union extend its activity so as to include general astrophysics, and that a committee be appointed to consider and report on the question of the classification of stellar spectra.

The committee appointed later consists of Professors Pickering (chairman), Schlesinger (secretary), Adams, Campbell, Frost, Hale, Hamy, Hartmann, Kapteyn, Newall, Plaskett, and Schwarzschild.

Professor Pickering explained the origin of the Harvard system of classification, saying that it was merely alphabetical at first and that afterwards it seemed best to drop some of the letters and change the order. It has now simmered down to fundamentally six types, designated *B, A, F, G, K,* and *M,* which may perhaps express a certain order in the evolution of stars. It would be extremely undesirable to introduce a new system until we know more certainly the true order of stellar evolution as indicated by their spectra, and it is to be hoped that no radical action will be taken.

Professor SCHUSTER said there is no danger that this committee will take any premature action. No one expects it to present at the next meeting any scheme of classification, but only to collect and present various opinions.

The following resolution was adopted:—

This conference learns with pleasure that it is proposed to erect a solar observatory in Japan.

For the meeting-place of the next conference invitations were presented from Bonn, Germany; Barcelona, Spain, and Rome, Italy. Professors KAYSER and KÜSTNER presented the claims of Bonn, Father CIRERA spoke in behalf of Barcelona, and Professor RICCO for Rome. It was voted that the meeting of the Solar Union of 1913 be held at Bonn, and that the time of meeting be fixed by the Executive Committee in consultation with Professors KAYSER and KÜSTNER.

The remainder of the session was taken up with the appointment of the various committees and votes of thanks to Professor and Mrs. HALE and the members of the observatory staff who had part in making the meeting so great a success.

Saturday morning was occupied with the descent from the mountain, and on Saturday evening the banquet given to the members of the conference at the Hotel Maryland by Professor and Mrs. HALE, at which about one hundred guests were seated, brought to a fitting close a memorable meeting.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1910.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon....	Sept. 3,	10^h 6^m	A.M.	New Moon	Oct. 3,	12^h 32^m	A.M.
First Quarter.	" 11,	12 11	P.M.	First Quarter ..	" 11,	5 40	A.M.
Full Moon....	" 18,	8 52	P.M.	Full Moon	" 18,	6 24	A.M.
Last Quarter..	" 25,	12 54	P.M.	Last Quarter ..	" 24,	9 48	P.M.

The autumnal equinox, the time when the Sun crosses the equator from north to south, occurs September 23d, 2 P.M., Pacific time.

Mercury is an evening star on September 1st, but sets less than an hour after sunset, and cannot well be seen by the naked eye. It reached greatest east elongation on August 30th, but is too far south of the Sun for convenient observation in the northern hemisphere. It passes inferior conjunction with the Sun on September 25th and becomes a morning star. Shortly after October 1st it rises an hour before sunrise and the interval grows larger until about the middle of the month, when it is an hour and a half, and does not diminish much until toward the end of the month. *Mercury* passes greatest west elongation on October 11th, the distance from the Sun being 18°, a small greatest elongation, as it occurs only three days after perihelion passage, but the planet is north of the Sun and is in the part of its orbit farthest north of the ecliptic. The period of naked-eye visibility is therefore rather unusually prolonged.

Venus is still a morning star and remains so throughout the two months' period, but draws too close to the Sun for easy naked-eye visibility toward the close. On September 1st it rises a little less than two hours before sunrise, on October 1st a little more than one hour before, and on October 31st only about half an hour before, rather too short a time for naked-eye view. It passes its perihelion on September 16th, but its orbit is so nearly circular that this makes little difference in its brightness or position. It passes conjunction with *Mercury* at a distance of 1° 55′ north on the morning of

October 3d, with *Mars* on the afternoon of October 22d at a distance of 45′, and with *Jupiter* on the morning of October 28th at a distance of only 20′. Unfortunately the last two conjunctions are too near the Sun for easy visibility. On September 11th it passes less than 1° north of the first magnitude star *Regulus, Alpha Leonis.*

Mars is still an evening star on September 1st, but sets less than half an hour after sunset. The Sun with its more rapid easterly motion among the stars draws gradually nearer to it, and the two bodies come to conjunction on September 27th. *Mars* now becomes a morning star, and the distance between Sun and planet increases, so that by the end of October *Mars* rises about an hour before sunrise. It is, however, about at its faintest, and it will hardly be possible to see it with the naked eye until after November 1st. It reaches its greatest actual distance from the Earth on September 13th, 246,000,000 miles, and its brightness is then only a little more than two per cent of its brightness at the opposition of 1909.

Jupiter is also an evening star on September 1st, rather farther away from the Sun than was *Mars,* and is therefore in rather better position for observation. It sets about an hour and one half after sunset at that date, and can therefore be easily seen in the evening twilight. But the gap between Sun and planet closes up rapidly, and by October 1st the planet sets less than half an hour after the Sun, and the two bodies come into conjunction on the evening of October 18th. *Jupiter* then becomes a morning star, and by the end of the month rises nearly an hour before sunrise.

Saturn is about the only one of the planets in good position for evening observation. On September 1st it rises at about 9 P. M., and on October 31st a little before sunset. It is therefore above the horizon nearly the entire night, and comes to opposition with the Sun at 1 A. M., October 27th. It is in a rather barren part of the constellation *Aries,* and moves about 3° westward and 1° southward during the month. The rings are now opening, so that observations on them are easy compared with conditions for several years back. The minor axis is nearly one third the length of the major. This fraction is about one half when the opening is widest. The variation from mini-

mum to maximum takes about seven years, one quarter of the planet's period.

Uranus is also in good position in the sky for evening observation, but identification is not very easy. It remains above the horizon until 1:30 A. M. on September 1st and until 9:30 P. M. on October 31st. It is nearly stationary in the constellation *Sagittarius*, moving slowly westward through September and eastward in October, but the whole motion is only a fraction of a degree. No conspicuous star is near, but the third-magnitude star *π Sagittarii* is about 8° west and 1° north, also the fifth-magnitude *h Sagittarii* is about 3° nearly due south.

Neptune rises at about 1:30 A. M. on September 1st and at a little before 10 P. M. on October 31st. It is in *Gemini*.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1910.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon	Nov. 1,	$5^h 56^m$ P.M.	New Moon	Dec. 1,	$1^h 11^m$ P.M.
First Quarter	" 9,	9 29 P.M.	First Quarter	" 9,	11 5 A.M.
Full Moon	" 16,	4 25 P.M.	Full Moon	" 16,	3 5 A.M.
Last Quarter	" 23,	10 13 A.M.	Last Quarter	" 23,	2 36 A.M.
			New Moon	" 31,	8 21 A.M.

The third and fourth eclipses of the year occur in November. A partial eclipse of the Sun November 1st. The region of visibility lies in the North Pacific Ocean, Northwestern Asia, and Alaska. The magnitude of greatest eclipse is about five-sixths of the Sun's diameter. The Sun will set during the eclipse in Alaska.

A total eclipse of the Moon November 16th. The entire eclipse can be seen in the eastern part of the United States, but only the latter part in the far west. The principal circumstances occur as follows, Pacific time:—

Moon enters shadow	Nov. 16,	$2^h 44^m$ P.M.
Total eclipse begins	" 16,	3 55 P.M.
Middle of the eclipse	" 16,	4 21 P.M.
Total eclipse ends	" 16,	4 47 P.M.
Moon leaves shadow	" 16,	5 58 P.M.

The Sun reaches the winter solstice and winter begins on the morning of December 22d.

Mercury is a morning star on November 1st, rising about half an hour before sunrise. It is therefore too near the Sun for naked-eye view. The planet overtakes the Sun and passes superior conjunction on the morning of November 12th. For the remainder of the year it is an evening star, and will be far enough away from the Sun for visibility in the evening twilight during the latter half of December. Greatest east elongation is reached on December 24th, and the planet will then set nearly an hour and one half after sunset., *Mercury* and *Venus* are in very close conjunction on the morning of November 3d, but are too near the Sun to be seen. Their minimum distance apart will be only 10′, about one third of the apparent diameter of the Sun or Moon.

Venus, like *Mercury*, changes from a morning to an evening star during the two months. On November 1st it rises about half an hour before sunrise, but rapidly approaches the Sun and passes superior conjunction on November 26th. The bodies then separate, but not as rapidly as the Sun and *Mercury*, and by the end of December *Venus* remains above the horizon a little more than half an hour after sunset. It will hardly be possible to see it with the naked eye until well into January, 1911.

Mars is now a morning star, rising on November 1st about an hour before sunrise, and this interval is increased to more than two hours by the end of December, so it will not be at all difficult to see during the latter part of December. During the two months it moves 44° eastward and 12° southward from *Virgo* through *Libra* into *Scorpio*. On December 31st it is about 5° north of the first magnitude star *Antares, α Scorpii*. Its distance from the Earth diminishes more than thirty millions of miles during the two months, and there is a consequent increase in brightness of nearly fifty per cent above the minimum. The planet will be easily seen, but is not likely to be quite as bright as *Antares*. Their colors will not be greatly different.

Jupiter is a morning star, rising a little less than an hour before sunrise on November 1st and shortly before 3 A. M. on December 31st. On November 1st it is very near *Mars*, the two planets coming into conjunction on the morning of No-

vember 4th. *Jupiter* is then 33′ north of *Mars,* a trifle more than the apparent diameter of the Sun or Moon. It moves about 11° eastward and about 4° southward from *Virgo* into *Libra.*

Saturn passed opposition with the Sun on October 27th and throughout November is above the horizon nearly the entire night. By the end of December it sets a little before 2 A. M. It is therefore in fine position for evening observation. It moves about 3° westward and 1° southward in the western part of *Aries.* No bright stars are near it. The opening of the rings as seen in the telescope remains about as it was during the summer and autumn.

Uranus is drawing nearer to the Sun. On November 1st it sets at about 9:30 P. M. and at the end of the year only an hour after sunset. It will not be possible to make naked-eye observations much after December 1st. It is still in the constellation *Sagittarius* and moves about 3° eastward during the two months. On December 26th it is in conjunction with *Mercury,* the latter being 36′ south. *Mercury* can be seen in the evening twilight at that date, as it has just passed greatest east elongation, but *Uranus* cannot then be seen without a telescope.

Neptune rises somewhat before 10 P. M. on November 1st and at about 5:30 on December 31st. It is in *Gemini.*

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE COLOR OF THE STARS IN THE GREAT NEBULA IN *ORION*.

In order to determine roughly the types of the stars in the *Orion* nebula, their colors were determined in the following manner. By means of bathed plates and a yellow screen, photographs of the region were secured on which the stars have about the same relative magnitudes as are found visually. Other photographs were made in the ordinary manner on Seed's 27 plates. The magnitudes were estimated by means of a scale which was calibrated by the estimates of the comparison stars for T *Orionis* which occur in the region under investigation. The mean magnitude of the stars was made the same for the visual (stained plates with screen) and photographic series; that is, the mean magnitude of all the 11^m stars in one series was made the same as the mean of the same stars in the other series. The difference between the photographic and visual intensity for any individual star gives the color on a scale which must be calibrated by stars of known color and type.

Since the stars in this region whose spectra are known are all blue and of nearly the same type, it was necessary to calibrate the color scale by means of another region. Plates of the field of the Ring Nebula in *Lyræ* were taken in same manner as in the case of the *Orion* field. In the *Lyra* field there are three faint stars of known type, concerning which Director E. C. PICKERING kindly furnished the data in a letter. As these stars were of types A, F, and M_a, it was possible to deduce the connection between spectral type and color as determined by the present method; for the increase in redness in passing from A to M

has been found by Professor KING and others to be quite regular. In the *Lyra* field the color of stars of type A is about zero; that of type M_a is + 2.0. In the *Orion* field the (relative) color of stars of type B is zero; that is, the great majority of the stars in this region have about the same color, and some of them are known to be type B. In the *Lyra* field, or in any field taken at random over the whole sky, the same is very likely to be true, about half of the stars are nearly the same in color and are A type, ranging perhaps from B8 to A5. The difference between the two fields must be borne in mind in interpreting the table of colors.

The stars in the *Orion* region appear to vary in color with the density of the surrounding nebulosity in the manner to be expected if the nebula exerted general absorbtion, but it cannot be said at present that this effect is not entirely due to "seeing" or to photographic causes. In the table that follows the colors have been corrected for this effect.

Regions free from nebulosity on a dense plate contain comparatively few stars. There is nothing unusual about the color of the stars in these empty spaces, aside from the point mentioned in the preceding paragraph. The edges of the regions of densest nebulosity contain a relatively large number of faint stars; it is of course impossible to say what numbers of faint stars are blotted out by the fogging of the plate in these dense regions.

In the table the color is given in such a way that a star whose color is positive is redder than the mean. Under each heading, >+.75, +.75, +.50, etc., is given the number of stars of the magnitude indicated at the left falling within this color division.

TABLE OF COLORS—*ORION* FIELD.

Mag.......	>+.75	+.75	+.50	+.25	±0	—.25	—.50	—.75	<—.75
<11......	1	1	1	12	14	12	3	1	0
11 to 12....	0	0	1	12	13	8	1	0	0
12 to 13....	0	1	4	16	22	16	6	1	0
All........	1	2	6	40	49	36	10	2	0

LYRA FIELD.

Mag.	>+.75	+.75	+.50	+.25	±0	—.25	—.50	—.75	<—.75
<11......	1	2	1	2	2	3	1	0	0
11 to 12....	1	2	4	2	2	5	2	2	0
12 to 13....	0	1	2	3	4	4	2	1	1
13 to 14....	2	4	8	11	18	18	8	1	1
All........	4	9	15	18	26	30	13	4	2

As the color increases $+.5$ per type in going from A to F, F to G, etc., on this scale, we can make an estimate of the numbers of stars of any given type. In the *Lyra* field (20′ square), which is probably representative of the sky as a whole, of the stars brighter than fourteenth magnitude two are probably of type K, ten or eleven of type G, some twenty-five of type F, about sixty-five of type A, and fifteen of type B and other blue stars. The color of the nebula star is -1.2. This is in accord with the results obtained by Keeler. No other star is bluer than $-.8$.

The stars of θ_1 and θ_2 *Orionis* and Bond 905 are of type O_e5, B1, and B3 respectively, and have color $-.2$, $+.1$, and $\pm.0$ respectively. Thus it seems that zero color must correspond to type B in this region. On this assumption there can be no more than one of the stars examined having a spectrum as advanced as G; only five that can be F; about 30 that may be A or B, while some eighty stars are almost certainly between O_e and B5. If the faint stars resemble those in other regions, in that half of them are A type, there may be several F type stars in this region; but there is little probability of more than one solar star—and certainly no star more advanced than solar—among those observed. A very red variable star was too faint to show on the plates used in this discussion. In the case of any individual star a rapid variation in intensity may have acted to give an erroneous color value. The fact that eighty-five per cent of the stars in the *Orion* region brighter than the thirteenth magnitude are comprised within a range of color corresponding to one and one-half spectral types is rather remarkable, the more so when one considers that there is good reason to think they are all in the neighborhood of B type. Only sixty per cent of the stars in the *Lyra* region are comprised within this range. The number of stars falls off rapidly as the stars become redder or bluer than the great central group in the *Orion* region, but relatively more rapidly on the red side. It is these last considerations which lead us to the conclusion that practically all the *Orion* stars are of type O_e to B5. There can be little question that most of the stars projected upon the nebula are actually within it and intimately connected therewith.

Some twenty variable stars were observed. They do not differ in color from the other stars, and are therefore blue, so they probably have short periods.

The plates used in this discussion were taken by Astronomer CURTIS with the Crossley reflector. The measurements were made at Minnesota, where this discussion was incorporated in a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy. KEIVIN BURNS.

MT. HAMILTON, September 26, 1910.

THE DEATH OF MR. JOHN MACDONALD.

The Lick Observatory has suffered loss through the death of the oldest member of its community, Mr. JOHN MACDONALD, who came to Mount Hamilton in 1880, as an employee of the James Lick Trust, when the principal duties of the Trust consisted in blasting off the irregular summit of the mountain, in order to prepare places for the buildings. On June 1, 1888, when the Lick Trust transferred the completed observatory to the government of the University of California, Mr. MACDONALD was appointed engineer, and foreman of the outside workmen. He remained in this capacity to the day of his death, at home, on September 18, 1910.

Mr. MACDONALD's continuous life of more than thirty years on Mount Hamilton thus covered the entire material history of the Lick Observatory. He leaves a wife, who has resided on Mount Hamilton continuously since the year 1885; a daughter Mary, who was the first child born to Lick Observatory people; and a daughter Eileen.

Mr. MACDONALD's affections for the Lick Observatory and all that concerned Mount Hamilton were highly developed. His services were at all times faithful and to the full extent of his ability. If calls were made upon him before or after working hours, on holidays, or at night, in sunshine or in severe storm, he was always willing and ready. Born in Nova Scotia in 1852, he possessed the strong character which we are accustomed to associate with natives of that land. The respect of the observatory community and observatory neighbors he always had. A line from Professor EDWARD S. HOLDEN, the

first director of the observatory, expresses the sentiments of everybody: "We all feel the same about this sterling, faithful man."

W. W. CAMPBELL.

GIFT OF METEORITE TO THE LICK OBSERVATORY.

Regent WILLIAM H. CROCKER has generously presented a meteorite to the Lick Observatory, University of California, which has been mounted suitably in the rotunda of the main building.

It is one of many found at Meteor Crater, six miles south of the Sunshine station of the Atchison, Topeka and Santa Fe Railway, Coconino County, Arizona. The weight of the meteorite is 92 kilograms (202 pounds). We are grateful for the gift of this member of the outside universe.

W. W. CAMPBELL.

MEMORIAL TO PROFESSOR KEELER.

A bronze tablet has been placed on the wall of the rotunda of the main building of the observatory in memory of Professor JAMES E. KEELER, astronomer in the Lick Observatory during the years 1888-91 and director of the Lick Observatory during the years 1898-1900. The tablet is a present to the observatory from six of Professor KEELER's personal friends.

W. W. CAMPBELL.

REPORTS OF OBSERVATORIES, 1909.

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

The work of this observatory has continued as in former years, and the time service and rating and issue of chronometers have been maintained as heretofore. Excavation and blasting preparatory to the building of a central power plant near the observatory have occasioned considerable disturbance to the instruments; and this development of the Navy Yard may necessitate the removal of the observatory to a new site before many years.

The researches in cosmogony mentioned in the last annual report have been greatly developed during the past year, and preliminary accounts of the work have been published in the *Astronomische Nachrichten*, in the *Publications* of this Society, and in other journals. This work consisted in the development of what is known as the capture theory of cosmical evolution, which will be more fully treated in Volume II of the writer's "Researches on the Evolution of the Stellar Systems," now in press and soon to be offered to the public. This is to be a large volume of more than six hundred pages, and has entailed a large amount of labor and the review of a subject of vast extent. But it is believed that the result will be to give cosmogony a much more secure foundation than has been possible heretofore.

The capture theory is based on dynamical principles, and illustrated by phenomena observed in the spiral nebulæ, the planetary system, the double and multiple stars and clusters, and the star-clouds of the Milky Way. The aim is to show that the planets were never detached from the Sun and the satellites never detached from their planets by rotation, as imagined by LAPLACE; but that all these bodies were formed in our solar nebula and have been captured and developed into the system we now observe, by motion in a resisting medium, which has greatly reduced the size of the orbits and rounded them up into almost perfect circles. This process of capture is shown to give the general laws of cosmical evolution, which heretofore have been sought in vain. All the principal phenomena of the solar system are brought into simple mutual relationship, and easily accounted for by known causes. Many of the

problems treated, such as the constancy of the length of the day, the origin of the terrestrial Moon, the secular acceleration of the Sun and Moon, the rotations and obliquities of the planets, etc., will open up new fields of thought which can hardly fail to be of great interest to astronomers and other men of science. It is shown by a satisfactory line of argument that, in general, there are planets about the fixed stars, and only the larger of these bodies may be recognized as visual and spectroscopic double and multiple stars.

May 24, 1910.

T. J. J. SEE,
Professor of Mathematics, U. S. Navy,
in charge of the Observatory.

CHAMBERLIN OBSERVATORY, UNIVERSITY PARK, COLORADO.

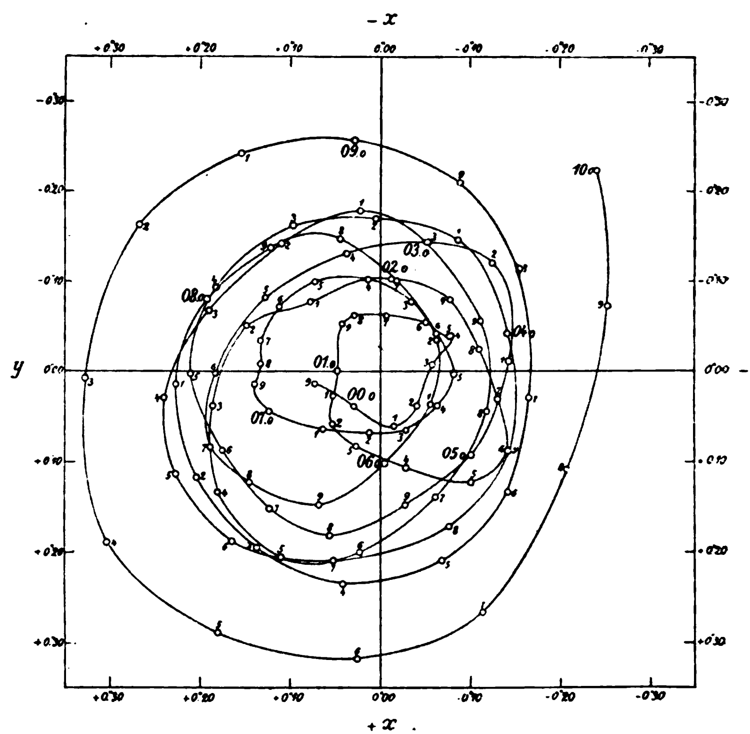
During the year 1909 the 20-inch equatorial was used almost exclusively for observations of comets. A good deal of work in reducing past observations was done by Miss MYRTLE L. RICHMOND and Mr. IRVING WHITEHEAD.

H. A. HOWE, *Director.*

GENERAL NOTES.

Variation of Latitude.—In the *Astronomische Nachrichten*, No. 4414, Dr. ALBRECHT has published provisional results for the variation of latitude from 1908.0 to 1910.0. The accompanying illustration has been taken from the above-mentioned number of the *Nachrichten*. It is seen at once that the amplitude of the variation during 1909 was much greater than that

Th. Albrecht. Verlauf der Polbewegung 1899.9—1910.0.



reached during any preceding year since observations were begun at the international stations. Dr. ALBRECHT comments upon the curve in the following way:—

"The great increase in the amplitude, during the year 1909, which considerably surpasses that of any preceding year, is of commanding moment. In the next place the very regular

progression of the curve in the years 1907-1909 is to be noticed. During this time the path of the pole is a steadily widening spiral. At the same time one sees, however, from the path of the pole during the first ten years of the latitude service, especially with reference to the maximum of amplitude corresponding to the years 1905 and 1909, that we are still far from being able to represent this motion of the pole by a simple mathematical formula." S. D. T.

Mount Tamalpais Excursion.—In the hope of adding something to the pleasure of the delegates to the recent meeting on Mount Wilson of the International Union for Co-operation in Solar Research, an invitation was extended by the Astronomical Society of the Pacific to all members, asking them to join in an excursion up Mount Tamalpais, planned for September 7th.

Unfortunately, the varying plans of the delegates, after the adjournment on Mount Wilson, so scattered the distinguished visitors that many of them found it impossible to accept the proffered courtesy. A small party was on hand, however, on the morning of the date fixed and a most enjoyable day followed.

Among the visitors who participated were the following: Professor HENRI CHRETIEN, of the Observatory of Nice, France; Professor F. W. DYSON, of the Royal Observatory of Edinburgh; Professor CHARLES FABRY, of the Observatory of Marseilles; Professor E. B. FROST, director of Yerkes Observatory; Professor J. VON HEPPERGER, of the Imperial Observatory of Vienna; Professor and Mrs. H. C. LORD, of the Emerson McMillan Observatory, Columbus, Ohio; Professor BRADFORD, of McMillan Observatory; Professor A. RICCO, of the Astro-Physical Observatory of Catania, Sicily, and Professor A. WOLFER, of the Polytechnic Observatory of Zurich, Switzerland.

The Astronomical Society of the Pacific was represented by Professor and Mrs. ALEXANDER G. MCADIE, of the U. S. Weather Bureau, Mr. and Mrs. JOHN D. GALLOWAY, Mr. and Mrs. CHARLES S. CUSHING, Mr. and Mrs. D. S. RICHARDSON, Professor R. T. CRAWFORD, and Mr. JOSÉ COSTA. There were

also present as local guests of the Society, Civil Engineer C. E. GRUNSKY and Mr. CHARLES E. HUDSON.

About two hours were spent on the mountain, during which lunch was served at the tavern, followed by an exhilarating ride, by gravity car, down to the Muir Woods, where the party was photographed.

The members of the Astronomical Society who acted as hosts on this pleasant occasion have reason to believe that their guests carried away none but pleasant impressions and that the day on Tamalpais will be remembered by them when many other events of their memorable trip to the Pacific Coast are forgotten.

Much credit is due to Professor MCADIE for his active part in arranging for the excursion, and the thanks of the Astronomical Society of the Pacific are also due to Mr. J. J. GEARY, general manager of the Northwestern Pacific Railroad Company and to Mr. C. F. RUNYON, president of the Tamalpais Scenic Railroad Company, through whose courtesy free transportation was furnished to the Society and its guests. Too much cannot be said in praise of the officers and employees of both these companies, all of whom united in showing every attention and kindness to the visiting scientists.

Katalog der Astronomischen Gesellschaft—Erste Abteilung, Zweites Stück—Zone $+70°$ *bis* $+75°$*—Berlin.*—The issuance of this catalogue completes the volumes for the first part of the great undertaking of the Astronomische Gesellschaft. The first part includes the positions of all stars down to the ninth magnitude between 80° north declination and 2° south. This volume, number two of the series, contains 3,461 stars between 69° 40′ and 75° 20′ northern declination at 1855. The observations were made under the direction of Professor L. COURVOISIER at the Royal Observatory at Berlin in the years from 1905 to 1908. The work is uniform with the rest of the series, with one exception, which, it seems to the writer, is an unfortunate departure. In the other volumes the equinox of reference is that of 1875.0, while in this one number the positions are referred to 1905.0. I cannot see a good and suf-

ficient reason for this change. On the other hand, I can foresee numerous errors in the reduction of star-places because of it.

Besides the usual explanatory introduction, and the catalogue itself, there are six appendices.

The Astronomische Gesellschaft is to be most highly complimented and congratulated for thus completing the first division of its work in giving a complete and comprehensive catalogue of star-positions. R. T. CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, August 4, 1910.

Modern Seismological Instruments at the Lick Observatory.—Up to the present the earthquake instruments at the Lick Observatory have been a small Ewing duplex seismograph and a large three-component Ewing disk seismograph. These have rendered efficient service in recording local shocks, but the need has long been felt for instruments capable of collecting the data for more distant shocks, which form so important a part of modern seismological research. Through a generous gift from Hon. W. R. HEARST, the observatory has been enabled to purchase and install two astatic Wiechert seismographs of modern pattern. The stationary mass weighs eighty kilos in the vertical instrument and two hundred kilos in the case of the instrument for registering the horizontal components. The instruments have been placed in a special room in the basement of the meridian circle house. A special break-circuit clock and the necessary self-recording thermographic and barographic instruments are included with the equipment. As soon as the heavy spring of the vertical instrument attains its steady state, the final adjustments will be made, the temperature cases erected, and regular records obtained.

W. W. CAMPBELL.

Halley's Comet.—At a recent meeting of the Royal Society of Edinburgh the subject of the passing of the Earth through the tail of Halley's Comet came up for discussion. The following account is taken from *The Scotsman*:—

Dr. JOHN AITKEN, F. R. S., made a communication entitled "Did the Tail of Halley's Comet Affect the Earth's Atmosphere?" Dr. AITKEN said that one of the theories regarding a comet's tail was that it was

composed of fine dust particles, and so it was thought that if they did pass through the tail of the comet, and if the tail was composed of dust particles, some of these might be found afterwards in the atmosphere of the Earth. Dr. AITKEN described investigations which he had made in May and June, at Morar and at Appin, to discover if the atmosphere had in any way been affected in this way by the passage of the comet. The normal amount of dust particles in the air at Morar when he had carried on such investigations previously was something like two hundred per cubic centimeter. During the time the comet was in the sky, with the wind in the northwest and under anticyclonic conditions, the increase of particles rose to three thousand per cubic centimeter, and there was greater haze than was usual with a northwest wind. All that could be said about it was that this indicated some change connected with the condition of the upper air, but there was no evidence to connect it with the comet. He had also made investigations as to the possible electrification of the air, but at Morar the result was nil. Observations had subsequently been made at Falkirk on the haze in the atmosphere since the comet passed across the sky. There had been an abnormal amount of haze during anticyclonic conditions, but it could not be connected either with the comet. He threw out the hint that the observatories might pay more attention than they did to haze observations.

Professor DYSON, of the Scottish Royal Observatory, said it seemed to be the view of a number of astronomers that the Earth did not go through the comet's tail at all. A bend on the tail, it was suggested, might have prevented the Earth going through it.

Dr. CARSE, of the Royal Observatory, said that at the observatory they made observations on the electrical state of the atmosphere during the time of the comet, and they pretty well agreed with those of Dr. AITKEN. The comet exercised very little influence on the state of the atmosphere. The records on their instrument differed very little before the comet was due to arrive and during the passage of the Earth through its tail, if it actually did pass through. The weather in Edinburgh at the time of the comet was very bad; but the electrical state of the atmosphere was not disturbed. Dr. CRIE, at Kew, had reported the same thing there.

Professor FORBES maintained that there could not be the slightest doubt that the Earth did pass through the tail of the comet. It could not help doing so, and he supported this view by describing views of the comet he had got on shipboard in the Atlantic from the 14th to 18th of May. There was no "sag," he said, in its tail. It was perfectly straight, and that had been a remarkable feature of Halley's Comet on its previous appearance.

Sir DAVID GILL, K. C. B., late of the Cape of Good Hope, exhibited a beautiful series of slides of the comet taken at Johannesburg, at the Cape, in Egypt, and America, which were greatly admired. He said it was very unlikely that they could get any evidence of what the tail of a comet was composed of by looking for dust particles in their own

atmosphere. Nobody knew what the tail of a comet was, and it would be difficult to think that particles in any degree comparable to the ordinary stuff they got in ordinary air could be transported through space at the enormous velocity at which a comet moved.

New Astronomer-Royal.—The King has been pleased to approve of the appointment of Mr. Frank Watson Dyson, F. R. S., Astronomer-Royal of Scotland, to the position of Astronomer-Royal, in succession to Sir William Christie, K. C. B., F. R. S., who will be retiring on October 1st.

PROFESSOR DYSON.

Professor Dyson, who is a son of the Rev. Watson Dyson, a Baptist minister, was born in 1868. He was educated at Nottingham Grammar School, Halifax Heath Grammar School (where he first displayed a marked ability for mathematics), and Bradford Grammar School. In 1886 he entered Trinity College, Cambridge, where he took his degree three years later. He remained at Cambridge as a Fellow till 1893. While at Cambridge he was Smith Prizeman and Isaac Newton Student. He acted as chief assistant to Sir William Christie at Greenwich Royal Observatory from 1894 till the end of 1905, when he received the appointment of Astronomer-Royal for Scotland, and professor of practical astronomy in Edinburgh University, in room of the late Professor Copeland. During the years he was engaged at Greenwich he assisted Sir William Christie in many important undertakings, and had gone abroad with him on eclipse expeditions. In 1900 they were together in Portugal; in 1905 in Tunis; while in 1901 he was sent by the Astronomer-Royal to observe the eclipse of that year. In 1909 he attended the Astrographic Conference in Paris. At present he is in America in connection with the Solar Conference, which is being held at the Mount Wilson Observatory, California. In 1901 he was appointed a Fellow of the Royal Society, London. He is the author of a large number of astronomical papers contributed to the Royal Astronomical Society, London, of which he was honorary secretary from 1899 to 1905, and to the Royal Society, of which he was for a time a member of Council. His first serious publication was contributed to the Philosophical Transactions of the Royal Society, London. He also contributed to that society's proceedings "Wave Length of H Lines, Derived from Photographs Taken at the Total Eclipse of 1900," and to the publications of the Royal Astronomical Society, London, monthly notices on the photographic charts of the heavens. To the proceedings of the Edinburgh Royal Society his contributions included "The Systematic Motions of the Stars" (1909). In the following year he published "Astronomy—a Handy Manual for Students." Since he came to Edinburgh, the work at the Royal Observatory, Blackford Hill, has been carried on under his direction with great activity. A profound mathematician, and with a thorough knowledge of astronomy, both

theoretical and practical, Professor DYSON is well known and highly esteemed in scientific circles.

SIR WILLIAM CHRISTIE.

Sir WILLIAM CHRISTIE has been Astronomer-Royal for nearly thirty years, which is almost exactly the average length of the tenure of the office by the eight Astronomers-Royal since the institution of the Royal Observatory at Greenwich. It was about the middle of the seventeenth century when the needs of navigation resulted in a scheme for the establishment of a National Observatory. To take proper observations at sea, mariners must have good tables for the movements of the Moon and other celestial bodies. Consulted regarding the preparation of such tables, JOHN FLAMSTEED made proposals which led to the establishment of the observatory at Greenwich in 1675, and to his appointment as Astronomer-Royal. It is of interest to note that he was succeeded in the office by EDMUND HALLEY, who gave his name to the famous comet, and that HALLEY was succeeded by BRADLEY, whose great achievement was the discovery of the aberration of light. Nowadays the office is not, as it used to be, for life. The staff at Greenwich Observatory are civil servants, subject to the same regulations as others, and Sir WILLIAM CHRISTIE goes into retirement, not from any failure of powers, but because he is sixty-five years of age.

He was thirty-six years of age when appointed in 1881, and his twenty-nine years as Astronomer-Royal have witnessed great advancements in astronomy. The transit circle has not yet been ousted as the chief instrument for Greenwich's traditional work, but important work is also done by the photographic plate, which in other departments has almost completely displaced visual observation. Under the retiring Astronomer-Royal, the observatory has been largely rebuilt, and its instrumental equipment greatly improved. Not being endowed with millions for the provision of giant telescopes, Greenwich has not competed with America in sensational discoveries, but has gone on its quiet way, piling up year after year those observations of the places of the stars which will be the groundwork of the astronomy of the future. A large share has been taken by Greenwich in the preparation of the great photographic atlas and catalogue of the stars. In spectroscopic work, too, it has kept abreast of the times.—*The Scotsman.*

Doctorates.—Science for August 19th gives tables showing the doctorates conferred by American universities at the 1910 commencements. Only two in astronomy were given—one by the University of Cincinnati to ELLIOTT SMITH, and the other by the University of Pittsburgh to ROBERT HORACE BAKER. Mr. SMITH's thesis was entitled "Personal Equation and Its Variation," and Mr. BAKER's, "The Spectroscopic Binary, *Beta Aurigæ*."

Astronomical and Astrophysical Society of America.—The eleventh annual meeting of the Astronomical and Astrophysical Society of America was held at Harvard College Observatory August 17th-19th. Thirty papers upon various phases of astronomical work were presented. Several of the foreign astronomers who later attended the Solar Conference at Mount Wilson were present. Professor EDWARD S. PICKERING was re-elected president of the society.

A New Observatory. — At Denison University, Granville, Ohio, the new astronomical observatory, presented by Mr. AMBROSE SWASEY, of Cleveland, was opened on June 15th. In the afternoon an address on "The Contribution of Astronomy to General Culture" was given by EDWIN B. FROST, of the Yerkes Observatory, and in the evening an illustrated lecture on "The Revelations of the Telescope" was delivered by JOHN A. BRASHEAR, of Pittsburgh.

The observatory is a very beautiful structure of white marble, and its interior finish is in excellent harmony with the elegant exterior. The principal instrument is a nine-inch telescope, with object-glass by the J. A. Brashear Company, with the latest style of mounting by Warner & Swasey, complete in every detail, and with a filar micrometer by the same firm, of which the donor is vice-president. A fine four-inch combined transit and zenith telescope is also provided, together with a chronograph, all by the same makers. The equipment also includes two Riefler clocks, for mean and for sidereal time, and a sidereal clock for the dome. The observatory is very well situated upon a high ridge commanding the horizon, and is admirably adapted for its purpose, principally educational, but the equipment is also sufficient for useful contributions to research.—*Science, June 24th.*

The Solar Conference.—At another place in this number of the *Publications* Professor WILSON has given a detailed account of the fourth Conference of the International Union for Co-operation in Solar Research. The list of members of the conference shows that many noted astronomers and physicists were present, and it was certainly a rare treat for some of us western astronomers, who have not been able to travel

extensively, to meet so many distinguished scientists, some of whose names have been known to us for a great many years. Professor WILSON's account is confined largely to the proceedings of the formal meetings of the conference, but I venture to suggest that the informal meetings in twos and threes and groups were equally important. Life at the Hotel Maryland, a morning at the instrument shops and physical laboratory, a garden party and a banquet, the trips up and down the mountain, and three days together on its summit gave many opportunities to bump up against one's old and new friends in order to compare notes, to discuss many questions, and to listen to an occasional good story.

Many interesting things were seen at the Pasadena offices, instrument shop, and physical laboratory, not least of which were the instruments with which the five-foot mirror was ground and that with which it is proposed to grind the 100-inch mirror when a suitable piece of glass is obtained. The rejected piece, occupying a corner of the shop, seemed to attract considerable attention. The glass is some ten or twelve inches thick and it is this element of thickness that makes the casting of a suitable piece difficult. Professor RITCHEY now has plans for building up a disk from three layers of glass, with intervening air spaces and various connecting pieces. He has tried it with a 30-inch reflector and is very positive that the plan will work satisfactorily for the 100-inch.

Mount Wilson is 5,886 feet high and the climb from Pasadena by the new wagon road was rather slow. The grades are steep, the turns too short to use four horses, there is no place to change horses, the day was hot, and the teams, hauling three-seated wagons with six passengers each, were nearly exhausted when the summit was reached. The trail is shorter and altogether a more agreeable way of reaching the summit.

The instrumental equipment on Mount Wilson consists of the Snow horizontal telescope, the 60-foot tower telescope, the 5-foot reflector, and the 150-foot tower telescope. The reflector was used by Professor RITCHEY on all three nights to show interesting objects to members of the conference. The seeing was good most of the time, and some fine views were obtained, the ring nebula in *Lyra* and *Saturn* being perhaps the most interesting objects shown. In the museum there were

exhibited many window transparencies made from negatives taken with the 5-foot reflector. These attracted a great deal of attention and are certainly very remarkable photographs. They seemed to the writer to stand in a class by themselves. The 150-foot tower telescope and observatory are the oddest looking combination in the world. The massive steel tower, with the little dome on top, looks about as much like the conventional observatory as a huge policeman with a little helmet perched on the crown of his head. The tower is not yet completed, but there is every reason to believe that it will prove eminently satisfactory.

The Smithsonian Observatory, with its equipment for the study of solar radiation, was also a point of interest to many.

Afternoon tea at the "monastery," served by the young lady assistants, added much to the pleasure of the busy days on the mountain top. To those who visited the observatory for the first time, one of the most impressive sights was the view of the valley at night, which was literally ablaze with the myriads of electric lights shining forth from Pasadena, Los Angeles, Long Beach, and neighboring towns. No such brilliant constellations were ever seen in the heavens.

The fourth conference will long be remembered. The warm hospitality of Dr. and Mrs. HALE, the thoughtful care and interest shown by Dr. HALE's co-workers, and the charming bit of color added by the young lady assistants will not soon be forgotten. S. D. T.

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OFFICERS OF THE SOCIETY.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first qurter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publicaion. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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THE MAIN BUILDING OF THE OBSERVATORY AT CÓRDOBA.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XXII. SAN FRANCISCO, CALIFORNIA, DECEMBER, 1910 No. 14

THE NATIONAL OBSERVATORY OF THE ARGENTINE REPUBLIC.

By C. D. PERRINE.

As no general description of the Córdoba Observatory nor of the work in progress here has appeared for some years, I have thought that a short account of its activities will be of interest.

As is well known, the Córdoba Observatory, or more properly, the Argentine National Observatory, was founded in 1870 when Dr. BENJAMIN APTHORP GOULD brought a large equipment of instruments and built the observatory under the auspices of the Argentine Government.

LOCATION OF THE OBSERVATORY.

The observatory is situated on the bluffs overlooking the city of Córdoba, about one mile from its central plaza and some thirty meters higher. The Rio Primero, a small river which carries but little water in the dry season, flows through the city.

The observatory is 430 meters above sea-level.

The observatory is almost at the level of the great pampa which stretches away to the north, east, and south.

To the west rise the Sierras de Córdoba, a range of granite mountains, the nearest of which are some twenty to twenty-five kilometers away. The peaks of the nearest of the range are from twelve to thirteen hundred meters in height. In these mountains is situated the water storage system which supplies Córdoba with electric current and the surrounding country with irrigation. It is said to be the second finest reservoir site in the world. These mountains contain some very picturesque scenery.

To the south and farther away rises a peculiar mountain formation, a long ridge part of which is nearly level on top.

This Pampa de Achala is some sixty-five kilometers in length and about eight in breadth and has an altitude of about two thousand meters. At the north end are the Gigantes, which have an altitude of 2,300 meters. At the south end rise the peaks of Champaqui to altitudes of nearly 2,900 meters. The top of this pampa is covered with a fine carpet of grass. The sides are very precipitous, especially that to the west.

BUILDINGS.

The original buildings comprised the main observatory building, the residence of the director to the east, and the assistants' residence to the west.

The observatory building originally contained four medium-sized rooms, two domes (east and west of the rooms with which they were connected by small passages), and two small domes, over the north and south entrances.

In the passage near the east dome is placed the old meridian circle.

The west dome formerly held the 12-inch equatorial. When the new Warner and Swasey mounting was installed, this instrument was removed to the east dome.

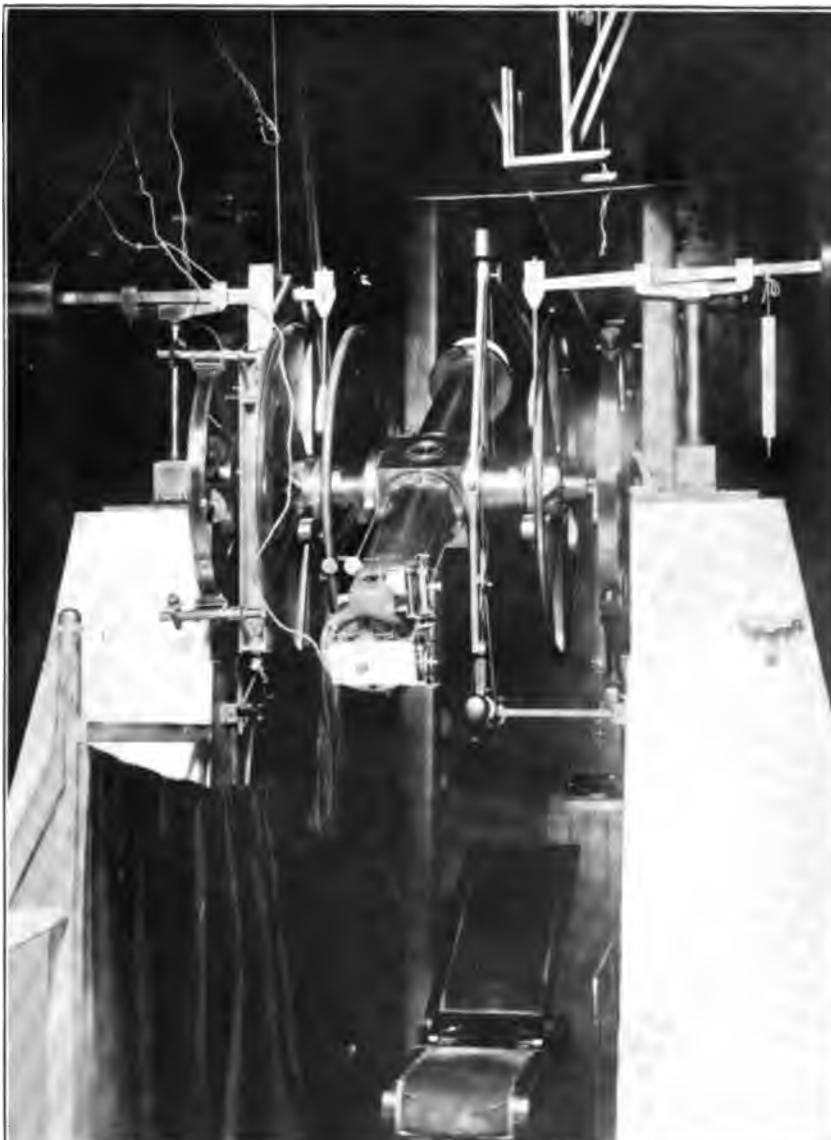
The 5-inch Clark equatorial was placed in the small dome over the north entrance.

The main building was subsequently enlarged by extending the meridian circle room to the full width of the building and by adding two rooms to the west.

There have also been added two small buildings to the south. One of these contains one large room used for the measuring department for the astrographic plates, and a basement containing the photographic dark-room.

The other small building to the south contains rooms for the janitor and for storage of supplies.

The building for the new meridian circle has been built to the south also and in the same meridian as that of the old instrument.



THE MERIDIAN CIRCLE OF THE NATIONAL OBSERVATORY AT CÓRDOBA.

INSTRUMENTS.

The principal instruments of the observatory are the following:—

13-inch astrographic telescope, with 7½-inch visual guiding telescope. Optical parts by HENRY BROS.; mounting by GAUTIER.

11¾-inch equatorial. Objective by HENRY FITZ; mounting by WARNER & SWASEY.

There is also a photographic lens of same size by HENRY G. FITZ.

190^{mm} meridian circle (new) by REPSOLD.

122^{mm} meridian circle (old) by REPSOLD.

5-inch equatorial by ALVAN CLARK & SONS.

5-inch photographic equatorial. Portrait lens by BRASHEAR; mounting by SÆGMÜLLER.

5-inch comet seeker by STEINHEIL.

3-inch portable transit and zenith telescope by FAUTH & Co.

The observatory possesses two Riefler clocks, one of which is arranged for constant pressure and temperature.

Five measuring engines are in use in the measurement of astrographic plates.

A new 7-inch photographic telescope of the portrait-lens type is completed and will soon be received in Córdoba. This instrument will be used first in making a survey of the Milky Way and other interesting regions of the southern sky, and for cometary photography.

A machine-shop is being installed to enable the instruments to be kept at the highest efficiency and to provide for prompt construction of new apparatus.

It is not necessary to recount in detail the early work of the observatory, for all astronomers are familiar with the great Córdoba General Catalog, containing the positions and the magnitudes of 33,500 stars, and the Uranometria Argentina. It will be remembered that the latter work was undertaken and the observations secured in the interval during which the meridian circle was being prepared. These works occupied the first fifteen years of the energies of the new observatory.

Upon the completion of the work for the General Catalog, in

1885, Dr. GOULD retired from the directorship and returned to his home in the United States. He took with him a series of negatives of thirty-five southern star clusters, which were subsequently measured under his direction. The resulting positions of over nine thousand stars were embodied in a volume issued in 1897, very shortly after his death. The volume was practically complete at the time of his death.

Upon Dr. GOULD's retirement in 1885, his first assistant, Dr. JOHN M. THOME, was appointed director. Dr. THOME was one of the members of the first staff which came to Argentina with Dr. GOULD.

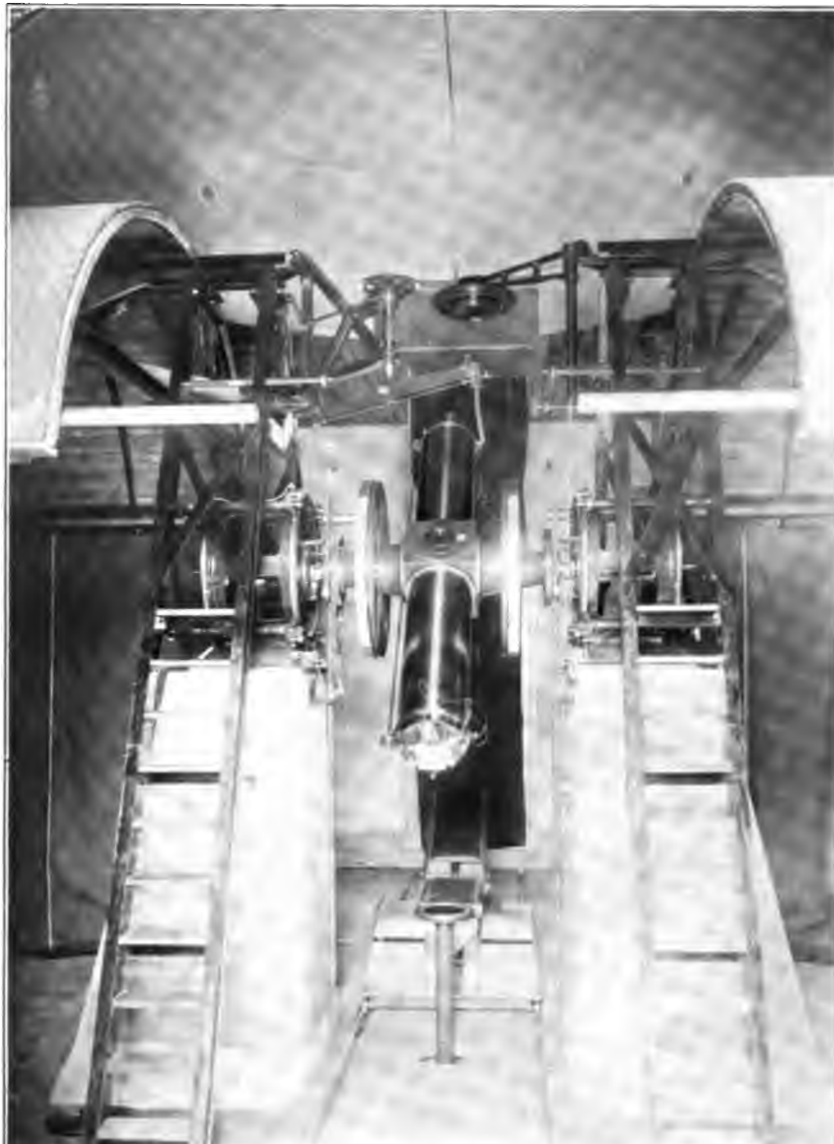
After the completion of the General Catalog, Dr. THOME began observations for his Durchmusterung. Three volumes of this work, containing 490,000 stars between —22° and —52°, have already been published. The observations for the zone —52° to —62° were nearly completed at the time of Dr. THOME's death in September, 1908. It is hoped to publish this volume soon, and to complete the work, including the maps, to the pole. Some observations have been made in the zone —62° to —72°.

In the years 1885-90, inclusive, the meridian circle work consisted of determinations of positions of stars scattered over the southern sky. These observations have been reduced and are being put in shape for early publication. A considerable number of stars observed in these years have proper motion.

In 1891 was begun the work of observing the stars of 9.2 magnitude and brighter, between the declinations —22° and —37°. These observations were completed in 1900. The reductions are complete. The revision is nearly completed when the results will be published in the form of a catalog for the epoch 1900.

In 1901 was begun the work of observing the stars to 9.0 magnitude in the zone —23° to —32°, for use in reducing the astrographic plates. About three fourths of the observations have been made.

At the Astrographic Conference of 1900 the zone —23° 0′ to —32° 0′ was placed in charge of the Argentine National Observatory. Some two years later the telescope was in position and the actual work of observing began.



THE NEW MERIDIAN CIRCLE OF THE NATIONAL OBSERVATORY AT CÓRDOBA.

The work of measurement is progressing rapidly and it is hoped to publish the first zone in about a year.

Thus far the chief energies have been devoted to the catalog work. Some difficulties have been encountered in making long exposures, which have delayed the chart work. These will be removed shortly, and the work of the chart will be pushed to completion along with the catalog.

Many comet observations have been made and published from time to time in the astronomical journals.

The observatory publications comprise nineteen quarto volumes and two atlases.

The new meridian circle has just been mounted and the preliminary try-out is in progress. All of the latest improvements are embodied in this instrument. The most notable are: The symmetrical steel tubes for the telescope; the overhead method of reversal, with pilot lights to guard against improper and insecure placing of lifting hooks; zenith mirror; heavy steel-frame system to support lifting crane and zenith mirror, with ladders giving easy access to overhead works; improved water-proof canopy cover for instrument; individual illumination of threads, micrometer heads, nadir and zenith mirror at eye-end; automatic rising nadir; improved system of counterbalancing; transit micrometer; provision for testing form of pivots, etc.

The details have been well worked out. The currents for lighting the eye-piece lamp and for the contact head are carried into the telescope by spring fingers at the axis and require no attention in reversing. The action of the counter-weights is likewise automatic and requires no attention in reversing.

Current for the small lights is obtained by stepping down the ordinary light current of 110 volts.

The illumination can be changed instantly at the eye-end from bright field to bright wire and the strength of the illumination varied by a small coal-resistance placed on the eye-end. The electric lamp is placed far enough away from the telescope-tube to prevent heating.

The mire may be observed by throwing a small lens into position between the eye-piece and the objective.

Double doors have been provided for the building for this

instrument. For differential work the method of "refrigerating" the instrument will be used, by shutting in the cooler night air—rather than placing dependence entirely upon ventilation.

A study of the meteorological conditions leads me to believe that the region about Córdoba will be found unusually favorable for astronomical work with large telescopes. Observation shows that the nights at the observatory are practically all perfectly calm; that the air is very transparent, and that there is a large number of nights in the year suitable for observing.

It is a very rare occurrence at the observatory to have any night wind. Light winds often occur during the day, but unless a storm condition is present, die out at or before sunset. There is reported to be very little night wind up to altitudes of one thousand meters. At two thousand meters the night winds are also said to be light.

The storms are practically all of a tropical nature, sudden and soon over. In two hours after a heavy storm I have seen the sky perfectly clear and the star images steady.

Meteorologists have suspected that there is a "Fœhn" effect over the region about Córdoba. This would seem to be an almost ideal condition for fine seeing, because instead of the mixed masses of air which ordinarily exist, due principally to rising or horizontal currents, such a region should have a practically homogeneous atmosphere around it, brought down by descending currents from the great, uniform mass above. To obtain the full advantage of such a condition, the observer should be on a peak rising some distance, perhaps not over two thousand feet, into the air.

At all events, Córdoba is sufficiently near to the great tropical belt to warrant the belief that light night winds are to be encountered at sufficient altitudes to gain the full transparency of the atmosphere.

The air here at the observatory is remarkably clear to be at the level of the pampa and so near a large city. I have had unexpectedly good views of the Milky Way and Magellanic Clouds.

Not only is the air unusually transparent and tranquil, but there are also a large number of nights suitable for observa-

THE 11¾-INCH EQUATORIAL OF THE NATIONAL OBSERVATORY AT CÓRDOBA.

tion. Unlike most other stations, the distribution of observing nights is very uniform throughout the year; there is no long unfavorable season. There are slightly more clear nights in winter, which is the dry season, than in summer, usually. A sample of the observing conditions during the past year may be had in the case of Halley's Comet. From November 30, 1909, when the comet was first observed, until February 3, 1910, when it was discontinued until after passing the Sun, observations were secured on forty-six nights out of sixty-six, including losses because of the Moon. From April 17th, when observations were resumed, to July 10th photographic observations were secured on sixty-seven nights out of a possible eighty-five. This winter has been a little more favorable than usual perhaps, but from two hundred to two hundred and fifty nights may be counted upon in the average year.

It is planned to send an expedition into the Sierras the coming summer to secure some photographic observations, and to obtain further data to aid in the selection of the most suitable observing station for a large telescope.

The chief energies of the observatory for several years must be devoted to astrometry, in which it has a number of obligations. It is hoped, however, to devote a portion of our resources to some of the modern problems.

RÉSUMÉ OF OBSERVATIONS OF HALLEY'S COMET AT CÓRDOBA.

By C. D. Perrine.

Theoretically, Halley's Comet became bright enough to be seen with our 12-inch equatorial about the first of December, 1909. It was first looked for on November 30th and found to be much brighter than was expected. From this date until February 3d it was observed for position. Estimates of size and brightness were made also. Observations were secured on twenty-one nights in December, twenty-two in January, and two in February, or forty-six nights in all. Observations were discontinued after February 3d because the comet was then

much better placed for northern observers, and any observations here would have been made at large zenith distances.

The comet was glimpsed on April 12th by Señor CHAUDET, but cloudy weather prevented observations until April 17th (astronomical time). Micrometer observations were made until the twenty-first, when the astrographic telescope was giving good position plates and the micrometer work was discontinued. During the period of greatest brightness all position observations were secured with the astrographic telescope, as follows:

April 18 to 30, on	9	nights
May, on	22	"
June, on	23	"
July, on	14	"
August, on	3	"

Micrometer observations were resumed on August 6th and continued until August 22d, after which the cômet was too low to be observed satisfactorily. It was seen on August 25th, but too far from a star (at such a large zenith distance) to make a good observation possible. It was very faint also.

The plan for photographic observations included position plates and others for details, with the astrograph; photographs with the 5-inch portrait lens for structure and extra-focal images for photometric determinations. It was also planned to secure a series of objective prism photographs with the portrait lens, but the prism which was ordered in October, 1909, has not yet arrived. Some observations were secured, however, with two small improvised instruments.

A very small camera was improvised to photograph the great extension of tail.

About four hundred negatives were secured with all the instruments. Short and long exposures were made with the astrographic telescope during the period of sufficient brightness and an excellent series of photographs obtained showing the detail in the head and inner tail. There is in general a complete change of structure in this region from day to day.

The series with the portrait lens is equally extensive and shows the outer nebulosity of the head and the tail.

Both of these series were continued into July. After the first week of July the comet was too faint and too small to justify such exposures.

Extra-focal negatives were secured with the portrait lens during the same period. This series comprises observations on forty nights between April 21st and July 8th.

A small objective-prism spectrograph was improvised with a 60° prism which was kindly loaned by the Department of Physics of the University of La Plata, and two lenses belonging to the observatory. One lens had a focal length of 65 centimeters and was used from May 21st to June 4th. The other had a focal length of 16 centimeters and aperture of 52 millimeters. This short focus lens was used from June 5th to July 28th, inclusive. Observations were secured with these two instruments on forty nights.

A small camera was constructed, using the field lens of an eye-piece. This lens has a diameter of 38 millimeters and focal length of approximately 5 centimeters; the field embraced was approximately 50° in diameter. The spherical aberration was large, but the lens served to record such a large diffuse area as the tail of this comet. Photographs were secured with this little instrument on May 5th, 6th, 7th, 8th, 11th, 12th, 13th, 17th, and 18th.

Probably the most interesting outburst recorded by our series of photographs was that which appears to have occurred about June 6.0 G. M. T. It is well shown on our plates with the portrait lens taken June 6th at 12^h G. M. T. and on the following two nights. The spectrum of this dislocation of the tail was recorded with the small objective-prism spectrograph on the same night. A casual examination shows no material difference in constitution between this outburst and the normal tail of the night before.

Many attempts were made to follow the comet with the 12-inch equatorial until after sunrise, with a view of obtaining meridian circle observations, but in no case could it be seen as late as sunrise.

The observations, including reproductions of a large number of the photographs obtained, will be issued in a special volume of the observatory publications.

Observatorio Nacional Argentino,
Córdoba, August 28, 1910.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1911.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter	..Jan. 7, $10^h\,20^m$ P.M.	First Quarter	..Feb. 6, $7^h\,28^m$ A.M.
Full Moon	.... " 14, 2 26 P.M.	Full Moon	... " 13, 2 37 A.M.
Last Quarter	.. " 21, 10 21 P.M.	Last Quarter	.. " 20, 7 44 P.M.
New Moon	... " 30, 1 45 A.M.	New Moon	... " 28, 4 31 P.M.

The Earth is in perihelion on January 3d at 7 A. M. Pacific time.

Mercury is an evening star at the beginning of January, setting rather more than an hour after sunset, but it is rapidly approaching the Sun and cannot be seen except for a day or two. It passes inferior conjunction and becomes a morning star on the morning of January 10th. It now recedes rapidly from the Sun, and by the middle of the month rises an hour before the Sun. It comes to greatest west elongation on the morning of February 2d, when its distance from the Sun is 25° and its rising time an hour and a half before sunrise. The interval is more than an hour until after the middle of the month. After this time it is too near the Sun for naked-eye observation. It is twice in conjunction with *Uranus*—on January 4th, when both are too near the Sun for observation, and again on February 10th, when the minimum distance of the planets is only 5′. This very close approach, however, occurs during daylight in this country.

Venus is an evening star, setting a little more than half an hour after sunset on January 1st, and the interval gradually increases until at the end of February it is nearly two hours. It is therefore in fairly good position for observation during the greater part of the two months' period, although it is in the part of its orbit beyond the Sun and therefore nearly at the position of minimum brightness. It is at its greatest actual distance from the Sun on January 7th, but its orbit is so nearly circular that this makes little difference with the brightness of the planet.

Mars is a morning star, rising about two and one-half hours before sunrise throughout the two months. At the beginning

of January it is about 4° north of the first magnitude red star *Antares*, *α Scorpii*, and from January 1st to February 28th it moves about 45° nearly due eastward from the constellation *Scorpio* through *Sagittarius* and nearly to the western boundary of *Capricornus*. *Mars* will come to opposition with the Sun again this year on November 24th, and has already at the beginning of the year begun to draw nearer the Earth and to appreciably increase in brightness; but it is still not far from its maximum distance from the Earth and its minimum brightness. During the two months its distance diminishes from 213 to 178 millions of miles, and its brightness increases from less than 5 per cent to a little more than 7 per cent of that which it will have next November. The opposition of 1911 will not be nearly so favorable as that of 1909, the distance of the planet from the Earth being nearly one-third greater and the maximum brightness only about one-half.

Jupiter rises a little after 2:30 in the morning on January 1st, shortly before 1 A. M. on February 1st, and shortly after 11 P. M. on February 28th. It moves about 5° eastward and 1° southward in the constellation *Libra*. At the beginning of February it passes about 1° north of *α Libræ*, the brightest star of the constellation.

Saturn is in fine position for evening observation throughout the two months. It remains above the horizon until nearly 2 A. M. on January 1st, until just before midnight on February 1st and until about 10 P. M. on February 28th. It is in the western part of the constellation *Aries*, a region very barren in bright stars, and moves about 3° eastward and 1° northward. As seen in the telescope, the apparent minor axis of the rings is a little more than one quarter that of the major axis and about two thirds of the apparent diameter of the planet.

Uranus is too close to the Sun for easy observation. At the beginning of January it is an evening star, setting about one hour after sunset. It comes to conjunction with the Sun on the morning of January 16th and becomes a morning star. At the end of February it rises about two hours before sunrise.

Neptune is in opposition with the Sun on January 11th and is then above the horizon nearly the entire night. It is moving slowly westward in the constellation *Gemini* south of *Castor* and *Pollux*, the principal stars of the constellation.

REPORTS OF OBSERVATORIES.

LICK ASTRONOMICAL DEPARTMENT,
LICK OBSERVATORY, MT. HAMILTON,
July 1, 1910.

To the President of the University of California.

SIR: I have the honor to submit herewith my fifth biennial report, covering the period July 1, 1908, to July 1, 1910.

Volume VIII, Publications of the Lick Observatory, containing seventy-one heliogravure full-page reproductions of Director KEELER's photographs of nebulæ as obtained with the Crossley reflector, as well as a list of 744 nebulæ discovered from the original negatives, was mailed to our correspondents in December, 1908. The reproductions were satisfactory in the main, and it is believed that they set a new standard of excellence. The work was well received by astronomers.

The financial difficulties connected with the publication of our results are well illustrated in the history of this volume. It was necessary to raise funds for this purpose by serious and prolonged personal effort. Beginning in 1902, private subscriptions were received amounting, in 1904, to approximately $2,400. The State Board of Examiners and the State Printer in 1904 authorized the transfer to this purpose of approximately $3,900 from special funds in the resources of the State Printing Office. Advancing prices during the years when the heliogravure reproductions were in progress added substantially to the original estimates of cost, and these advances were met from successive annual budgets of the observatory. The last bill was paid in the spring of 1910, the financial operations of issuing one volume having extended through eight years.

Upon the completion of the Keeler volume, it was hoped that we could proceed promptly with the reproduction of our splendid and unique series of solar coronas, coronal, and chromospheric spectra, etc., as illustrations for a proposed volume to contain the results of the Phœbe A. Hearst Eclipse Expedition to Chile and of the Crocker Eclipse Expeditions to India, Georgia, Sumatra, Egypt, Spain, and Flint Island. A State appropriation for this purpose was requested by the Board

of Regents and favorably reported upon by the last Legislature, but the appropriation was not made effective.

The publication of Professor BARNARD's photographs of the Milky Way and comets obtained on Mount Hamilton in the years 1890-95, referred to in my last report, has made some progress in the biennial period. Professor BARNARD is hopeful that the reproductions will be completed in the coming winter. Funds for this purpose were collected by Professor BARNARD from generous friends in California before his resignation from the Lick Observatory staff in 1895.

The number of *Lick Observatory Bulletins* issued to date is 182, extending into Volume VI. The increased cost of printing renders it impossible to avoid annual deficits in the special fund appropriated for this purpose. Exceedingly regrettable delays in the issuance of *Bulletins* now and then are apparently unavoidable, owing to limited facilities in the university printing-office. For example: In the publication of *Bulletin* No. 181 more than sixty days passed between the sending of the manuscript to the University Press and the supplying of first proof sheets; about seventy days passed between our returning of the first proofs and our receipt of the second proofs; and another delay ensued before the *Bulletin* went to press. Altogether the publication of this *Bulletin* consumed five months.

It is with deep regret that we record the lamented death of DARIUS OGDEN MILLS, former Regent of the University, member of Mr. LICK's first board of trustees for the Lick Observatory, and donor of the D. O. Mills Expedition to the southern hemisphere, as well as of two Mills spectrographs at Mount Hamilton. His interest in the spectrographic work, for which he made provision, was intellectual as well as financial. A year and a half before the date of his death, the observations secured during the first period of the D. O. Mills Expedition by Professor WRIGHT were ready in manuscript form for publication. Mr. MILLS's inquiries evinced interest in these results, and hopes were extended to him from time to time that they would be published. Uncertainties as to whether and when the State Printing Office could undertake the work—uncertainties over which I had no control—delayed the publication from time to time until it was too late for Mr. MILLS to see the completed

volume. My estimate of the expense of the D. O. Mills Expedition had contained no item to provide for publication, for our results in the past, obtained on Mount Hamilton or on the Hearst and Crocker eclipse expeditions, had been published by the State printer without question, and there was no reason to foresee that this method would fail in the case referred to. After nearly two years of unresolved uncertainty, and shortly after Mr. MILLS's death, the unfortunate delay was mentioned to Mrs. HEARST, Regent of the University of California, and she most generously and with the most unselfish of good wishes to all concerned made private provision for publishing the results by the University Press. Her gift will be available in a few weeks, and it is hoped that the printed results will be ready for distribution soon.

Regrets have been expressed by many astronomers, orally, in letters and in print, that these results should be so tardily made available; but uncertainties over which I had no control prevented publication in the usual channels, and also prevented efforts to secure private funds for the purpose. This explanation seems essential.

It will have appeared that our publication problems have been troublesome and discouraging, with consequences which may be more than regrettable. In the abstract, it must be an unwise policy which locks up the results of extensive investigations.

A grant of four thousand dollars was made by the Carnegie Institution of Washington in 1908, in continuation of similar grants in earlier years, for the employment of assistants and computers. On this foundation the following Carnegie assistants have been employed: Miss A. M. HOBE, July 1, 1908, to July 1, 1910; Miss L. B. ALLEN, July 1, 1908, to July 25, 1909; Mr. KEIVIN BURNS, June 1, 1909, to November 1, 1909; Mr. KRISTIAN LOWS, October 1, 1909, to May 1, 1910.

A few computers have also been employed on this foundation in piece work. These resources have been devoted almost exclusively during the biennial period to the measurement and reduction of spectrograms for determining the radial velocities of stars. Acknowledgments of this assistance are gratefully made.

Early in 1909 the Regents of the university generously appropriated the sum of ten thousand dollars to complete the fire-proof building, with safe storage vaults to contain our collection of celestial photographs, and rooms suitable for the various requirements of photographic research. The building was finished in the spring of 1910, the appropriation having permitted the carrying out of the original plans, with the addition of a few desirable improvements. Several of the rooms are in use, and it is planned to transfer all the photographs, all the records, and all unused parts of instruments, in the latter part of the present year, after the concrete walls shall have been thoroughly dried out by the summer weather.

The seismographic installation, generously provided by Honorable William R. Hearst, has been received. A special concrete room has been constructed in the basement of the meridian circle, with appropriate approaches, and the instruments will be erected and used before the close of the present year. The purchases had been delayed, in accordance with the advice of experienced seismologists, in order to receive the benefit of pending improvements in the instruments.

It has been my ambition to make the library of the observatory as complete as possible in all departments closely related to the lines of research undertaken here, and to have it include the more important available works on the history of astronomy. The President and Regents of the university gave generous expression to their approval of this policy by appropriating the sum of two thousand dollars for additions to the library, early in the year 1910.

The Crossley reflector, in common with other similar instruments, was designed to follow the subject under photographic observation not only approximately by means of the excellent driving clock, but accurately by delicate motions given directly to the small plate holder carriage. This is the best known plan for following the so-called fixed objects. In order to utilize this powerful instrument in securing large-scale photographs of objects which move rapidly amongst the stars,—of comets, for example, and especially of Halley's Comet,—it was necessary to arrange to give delicate slow motion to the entire instrument, in right ascension and declination. This involved the installa-

tion of anti-friction bearings for the two ends of the polar axis and for the two supports of the declination axis, and of two end-thrust bearings for the declination axis. The instrument was dismounted in January, 1910, while the large castings were taken to San Jose for turning out to receive the roller axis bearings and the end-thrust ball bearings, which had been constructed previously. The instrument was out of commission only ten days. These improvements have been very successful. Though the moving parts of the telescope weigh about six tons, a pull of four pounds on the end of the tube is sufficient to move the telescope in declination, and a pull of eleven pounds moves it in right ascension.

At the same time, a guiding telescope of aperture three and one-half inches and focal length equal to that of the large mirror, seventeen feet five inches, was fixed on the side of the main telescope tube. This small telescope, whose eye-piece is supplied with electrically illuminated wires, serves well its purpose of guiding upon moving objects. The original mechanism for moving the telescope slowly in declination by an observer at the upper end of the main telescope has been extended to the lower end, where it is within convenient reach of the observer at the eye-piece of the new guiding telescope.

A special room for silvering the mirrors has been constructed within the lower story of the Crossley dome, and a number of other minor improvements have been made.

All the walks, hitherto of wooden construction, have been replaced within the biennial period: the gently inclined walks with heavy planking, and galvanized iron pipe railings set in concrete; and the level walks with heavy concrete. Several new walks, joining frequented points, have been laid with concrete.

Prior to 1910 there were no restrictions as to driving over all parts of the summit unoccupied by buildings. A cement curbing, starting at the north end of the main building, running around the north and east sides of the meridian house, and thence to a point near the northeast entrance to the great dome, now limits vehicles to one definite narrow driveway near the north, east and south borders of the flat summit, and to the flat on the west side of the main building. All other free

space on the summit has been graded with rich soil, and a good start on lawns has been made.

In the early months of 1909 and 1910, afforestation immediately around the summit was undertaken, in charge of Mr. WRIGHT, by planting acorns, of Mount Hamilton growth, and many hundreds of nursery trees one and two years old. The number of new trees living at the date of this report is disappointingly small, but the experience gained should be useful in guiding similar work, on a larger scale, in future years.

We are under great obligations to the Forestry Department of the United States for advice, and for liberal supplies of young trees.

It is scarcely possible for dwellers in ordinary locations to realize the difficulties of lawn-making and tree-growing on Mount Hamilton. The soil is thin and the drainage is perfect; there are no summer fogs and clouds; the air is of desert dryness; and the dryness is in effect accentuated by prevailing winds. New trees must be liberally irrigated through several summers, and especially during those months when the springs are running lowest. Reservoirs for the storage of the water surplusage of winter and spring must be the starting point in plans for lawns and trees.

In the summer of 1909 the Regents appropriated the sum of twenty-seven hundred dollars to erect a steel tank, of one hundred and sixty thousand gallons capacity, on Kepler Peak, to supplement the storage capacity of the brick and wooden tanks (160,000) already installed there. The heavy steel tank, on a carefully prepared foundation, was completed in September, 1909. Notwithstanding the shortage of rainfall in the past season, and the heavy withdrawal for irrigation, all the storage reservoirs were full on July 1, 1910.

The slopes immediately below the flat summit are composed of broken rock, dumped over the edge when the summit was leveled off, about the year 1880. Wherever this rock has disintegrated during the intervening thirty years, the native grasses and wild oats have obtained a foothold. It is planned to assist this process by throwing a light coating of soil, containing the seeds of these growths, over the more conspicuous of these slopes. It is believed that much can be done in this

manner, and at little expense, to cover the forbidding rock slopes and slightly to reduce radiation effects in the atmosphere immediately surrounding the domes containing the telescopes.

The section of the overhead electric line running from the switchboard down to the Crossley dome suffered frequently and severely from the high winds of winter, and it was wrecked several times. This section was undergrounded in 1909, assistance to that end having been generously afforded by the Pacific Gas and Electric Company, of San Francisco, and by the Standard Underground Cable Company, of Pittsburgh, Pennsylvania. Service over this line has not been interrupted since the change was made. The overhead lines running eastward from the switchboard should be undergrounded, and it is hoped that this improvement may be afforded in the near future.

In August, 1909, the rates of the stage company, which supplied mail, passenger and freight service between San Jose and Mount Hamilton, were in effect more than doubled. In this emergency the passenger and freight service essential to the observatory and its people was supplied by our own wagons, mule team, and driver, from September 1, 1909, to July 1, 1910. Two round trips per week to San Jose were made.

The schedule of the horse stages has been lengthened from time to time during the past twenty years, but never shortened. In various ways the service grew poorer. One reason for this lay in the fact that travelers were growing tired of slow stages, and more visitors were coming to the observatory in automobiles than in carriages. When the Post Office Department requested bids for carrying the mails during the four-year period beginning on July 1, 1910, none were entered by horse stages. The department generously expressed a willingness to pay an increased sum, up to a certain limit, for an expedited automobile mail service. The subject was not easy of agreement, and it was feared for a time that the six day per week mail service must be reduced to a three day per week mail service. Fortunately, at the last moment, arrangements were made acceptable to the department and to the automobile stage company, and it is confidently expected that the automobile service for the mails, passengers and small freight will be thoroughly modern.

Many of the photographs secured at the Flint Island eclipse of January 3, 1908, have been submitted to careful study with interesting results.

It was feared that the rain in the five minutes immediately preceding totality had injured the photographs forming the basis of search for intramercurial planets, as the water got inside of the camera and ran across the dry plates in the plate holders. Dr. PERRINE compared the images of stars recorded on these plates with the charts of the same region of sky formed photographically at Mount Hamilton before the eclipse. The images of 506 stars were found on the Flint Island plates. Several of these are fainter than 9.0 visual magnitude, and a large number are between 8.0 and 9.0. From the distribution of the fainter stars on the plates it appears that the search was uniformly successful throughout the entire critical region, and that they suffered no detriment from the rain. In fact, the water-streaked areas on the plates recorded their quota of stars as faithfully as the unstained areas.

All the images were identified as known stars and planets. The taking of duplicate negatives covering the entire region enabled a definite decision to be made concerning other suspected images on any of the plates, and all such were found to be the usual and unavoidable defects in the films. These observations make it practically certain that there are no intramercurial bodies of 8.0 visual magnitude, or brighter, in or near the plane of the Sun's equator, with elongation distances of 12°, or less, as viewed from the Earth.

It has been shown by Dr. PERRINE that a planetary body of 8.0 magnitude in the region searched could hardly be more than twenty-five or thirty miles in diameter, and that it would require fully one million such objects as dense as *Mercury* to produce the observed disturbances in *Mercury's* motion. Considering this fact, and the greatly increased number of objects required if they should be one or two magnitudes fainter than the limit of our search, I think we may say that the intramercurial problem in its original significance is concluded as to its observational side. It would not be surprising if a number of small planets should be found on the occasion of future eclipses, but it is felt that these would be totally inadequate to

supply the disturbing attractions upon the inner planets, which gave origin to the so-called intramercurial-planet problem.

Dr. AITKEN has continued the double star survey of the northern sky according to the systematic plans described in previous reports. Three hundred and eighty-five new double stars were discovered, in the biennial period, with the 36-inch refractor. The two component stars in every case are less than five seconds of arc apart. This survey as carried on at Mount Hamilton will extend to — 22° declination and include all stars as bright as 9.0 visual magnitude. Fully ninety per cent of the survey of the northern sky is now complete. The unobserved areas are in the winter sky. Given average winter observing conditions, I shall hope to note the completion of the survey in my next report. Thus far, 3,500 close double stars have been discovered, as one result of the survey: 1,300 + by Professor HUSSEY and 2,200 by Dr. AITKEN.

The problems of the stellar system cannot be regarded as solved unless they are based upon homogeneous observations extending over the entire sky. There is unanimity of opinion amongst astronomers that the Lick Observatory double-star survey, extending from the north pole of the sky to 22° south of the equator, should be extended on to the south pole of the sky as early as practicable, and that Dr. AITKEN is the logical man for this work. Given a first-class refracting telescope of from 20 to 27 inches aperture, at a good location in the southern hemisphere, four years of observing should suffice to make the survey complete. Careful consideration has been given to the subject of ways and means for accomplishing this purpose. Two practicable plans appear to be available. I describe one:

The government of the South African Union is constructing a well-equipped observatory at Johannesburg in the Transvaal. The principal instrument called for in the plans is the 26-inch refracting telescope now under construction by Sir HOWARD GRUBB. The maker has promised delivery early in the year 1911. Director INNES of the Johannesburg Observatory, with exceeding generosity, has offered the use of the 26-inch refractor, without charge, to Dr. AITKEN, in order that he may complete the Lick Observatory double-star survey. According to

this proposal, Director INNES would use the telescope about three hours of each clear night and Dr. AITKEN the remainder of the night. There should be no special difficulty in securing funds to cover the expense of the expedition, and it is hoped that Dr. AITKEN may enter upon these plans immediately following the completion of the telescope.

It is scarcely necessary to repeat the truism that the great value of this splendid survey lies not in the discoveries of more double stars themselves, but in the increased opportunity which these discoveries will afford in the future study of double stars in particular, and of the structure of the stellar universe in general. For example: Utilizing the results in a small section of the sky, Dr. AITKEN has made a statistical study of the number and distribution of visual double stars and of the relations existing between the angular separation, the numbers and the magnitudes of the systems whose components are closer than five seconds of arc. He has found that the proportion of stars whose components are really close to each other is systematically smaller and smaller as he passes from brighter stars to fainter stars. This surprising result should, of course, be confirmed by studies based upon the double stars distributed over the entire sky as soon as the survey shall have been finished. We have here a mere suggestion of the fruits which must come out of the complete survey.

Dr. AITKEN has maintained his micrometer observations of a short selected list of well-known double stars which are in rapid orbital motion.

New orbits have been computed for the binary stars β 612, 55 *Tauri*, 4 *Aquarii*, and a preliminary orbit for π_2 *Ursæ Minoris*.

Dr. AITKEN observed the position of the two satellites of *Mars* with reference to the planet on five nights in September and October, 1909. The measures involved more than 2,700 micrometer settings. The eclipses of *Saturn's* satellites were observed on three nights.

The determination of the solar parallax, as derived from the photographs of *Eros* taken with the Crossley reflector in 1900, and measured here by means of a special grant from the Carnegie Institution of Washington during the years 1905-

08, was brought to a conclusion early in 1909 by Dr. PERRINE. Two methods of solution, essentially independent, led to the values 8″.0070 and 8″.0064. There was no apparent reason why one of these values should be given greater weight than the other, and the simple mean was adopted as the final result: *Solar parallax* = **8″.8067**. Confidence is felt that this value must be near the truth, and as accurate as the original mounting of the Crossley reflector would permit us to obtain, especially as it was not possible to reach an essentially different value by any reasonable variation in the methods of combining the results for the different nights of observation. The work is undergoing publication by the Carnegie Institution.

When the spectrum of *Mars* was under observation on Mount Hamilton in 1894, for the purpose of detecting the presence of water vapor in the planet's atmosphere, I found that the water vapor in the Earth's atmosphere was, and is, the great obstacle in the way of success. I then resolved to repeat the observations from Mount Whitney, the highest point in the United States, when the planet would again come into position favorable for the purpose. At this elevation, 14,500 feet, about four-fifths of the vapor contained in the atmosphere should be below the observer, and but one-fifth above him. The planet would be favorably placed in August-September, 1909, when *Mars* would be near the Earth and high above the horizon at the time of the year when Mount Whitney could be ascended with instruments. Late in August, 1908, I ascended Mount Whitney, in order to determine the limiting sizes of the instruments which could be transported safely over the rocky trails on the backs of pack animals, and to plan the living arrangements for the proposed expedition of 1909. Director ABBOT of the Smithsonian Observatory accompanied me. Remaining on the summit throughout the night of August 24, 1908, we found low relative and absolute humidities, which promised well for the contemplated observations of the spectrum of *Mars*.

Before leaving the summit it was decided that observations in 1909, requiring residence of a week or more on the summit, should not be undertaken unless a building of some kind could be erected as a shelter in case of storm. The question was presented to Dr. WALCOTT, secretary of the Smithsonian In-

stitution, and through his lively interest an appropriation was made from the Hodgkins Fund to provide a permanent stone, steel, and glass building containing three rooms for the shelter of the 1909 and future expeditions.

As soon as the shelter was assured, Mr. WM. H. CROCKER, Regent of the University of California, made generous provision for all of the expenses of the expedition from the Lick Observatory, including such pieces of new apparatus as were required to complete the equipment.

The members of the expedition were Director CAMPBELL, Assistant Astronomer ALBRECHT, and Carpenter HOOVER, of the Lick Observatory; Dr. MILLER, of San Jose, who cared for the health of the party; Professor ALEXANDER MCADIE, who was detailed by the chief of the Weather Bureau to accompany the expedition; Mr. W. L. SKINNER, of Lone Pine; and Mr. G. F. MARSH, of Lone Pine, who met us on the summit, he having completed the building on the morning of our arrival.

We were on the summit of Mount Whitney from August 28 to September 4, 1909. The atmospheric conditions were extremely favorable on the nights of September 1st and 2d, and successful photographs of the spectra of *Mars* and the Moon were obtained.

The conclusion drawn from the observations, in view of the extreme faintness and apparent equality of the water-vapor absorption bands in the Martian and lunar spectra, as observed at small zenith distances through a minimum of water vapor, is that the quantity of any water vapor existing in the equatorial atmosphere of *Mars* at the time these observations were made was too slight to be detected by available spectrographic methods. Recalling that the rays as photographed had passed from the Sun through the planet's atmosphere, for the most part down to its surface and out again to us, thus traversing the Martian atmosphere twice, and multiplying the absorptive effect, it is difficult to conceive that the quantity of vapor above unit area on *Mars* could exceed or equal the quantity of terrestrial water vapor above the same area on Mount Whitney.

In particular, it is not contended that *Mars* has no water vapor. The waxing and waning of the polar caps are usually considered as evidence of the existence of water vapor and

snow on that planet, and this is the opinion which I have always held; but the quantity of vapor must be too slight for detection by the insensitive spectrographic method referred to.

There has been a disposition in certain quarters to say that the conditions on Mount Whitney were really not favorable for this purpose, because the observations were made in the summer season and the higher atmospheric strata of the Earth must have contained much water vapor. It need only be remarked that the evidences of water vapor absorption by the terrestrial and Martian atmospheres combined were exceedingly slight, and it should be apparent to everyone that the more vapor there was above Mount Whitney the less there could have been in the Martian atmosphere in order to produce the minute observed effect.

It is well known that several astronomers of a generation ago utilized the Doppler-Fizeau displacements of spectral lines to distinguish, in the observed solar spectrum, between absorption lines of truly solar origin and the absorption lines of water vapor and oxygen introduced by the earth's atmosphere. The approach of the eastern edge of the Sun toward the terrestrial observer and the recession of the western edge from him, displaced the lines of solar origin to the violet and red, respectively, from their normal positions, whereas the terrestrial lines remained in their normal positions.

It was realized by me as early as 1896 that the same principle could be applied in observing the spectrum of *Mars* for evidence of water vapor and oxygen absorption in that planet's atmosphere, provided the spectrum could be photographed with high dispersion; for when *Mars* is at or near quadrature with reference to the Earth, the two planets are relatively approaching or receding from one another, 20 kilometers per second, more or less, depending upon the concurrence of favorable circumstances. If the spectrum of *Mars* were photographed under these conditions, the absorption lines introduced by the Martian atmosphere and the absorption lines introduced by the Earth's atmosphere should be seen separate and side by side on the photographic plate. *Mars* was favorably situated for this purpose in January and February, 1910. A special high dispersion spectrograph was constructed, partly from WM. H.

CROCKER funds, partly from funds granted by the Rumford Committee of the American Academy, and partly from university funds. The necessary observations of the Martian spectrum and the lunar spectrum for comparison were obtained in January, February, and March by Dr. ALBRECHT, who also measured the plates. The dispersion employed was such that the water vapor lines originating in our atmosphere and any originating in *Mars's* atmosphere should have appeared side by side, though not entirely separate. If the absorptions by the two planets were equal, the two sets of lines of equal intensities should, in effect, have appeared as broad lines of double width, and their centers should have been displaced by one-half of the relative velocity of the Earth and *Mars.* The facts are that the terrestrial lines were not bordered by Martian lines nor increased in width.

When the micrometer wire was set successively in the positions which Martian absorption lines would occupy, no traces of absorption were found in these positions. In fact, Martian absorption did not exist to such an extent as to be visible in the spectrum, nor to influence the measurements referred to. Similar results were obtained for the oxygen lines. The quantity of water vapor in the Martian atmosphere must have been small in comparison with that contained in the atmosphere above Mount Hamilton under the excellent conditions prevailing at the time of observation. Likewise, the quantity of oxygen above unit area on *Mars* must have been small in comparison with that above the same area on the Earth. It should be repeated that the rays of light utilized had passed, in effect, at least twice through the Martian atmosphere, thus multiplying any existing absorptive effects.

The return of Halley's Comet was anticipated with considerable interest, and preparations were made to secure series of observations, as complete as possible.

In the interval, September 12, 1909, to July 1, 1910, Dr. CURTIS obtained three hundred and sixty direct photographs of the comet on ninety-one nights. Two hundred and two of these were made with the Crossley reflector, one hundred and eighteen with 5-inch and 6-inch portrait lenses, and forty with small lenses whose ratios of aperture to focal length were

unusually great. The four smaller cameras were mounted on the massive tube of the Crossley reflector, and great steadiness and accuracy in following were thus maintained.

It appears probable that our photographs of Halley's Comet form the most extensive series extant. They are of great interest now, and they should be of consummate interest seventy-five years later when the return of the comet is imminent. A large selection from the series should be made for reproduction; but here we encounter again the publication problem. The sum of six hundred dollars should be used for this purpose, and we hope that a way may be found to issue an exhaustive paper, completely illustrated, in one of our regular mediums of publication. Dr. CURTIS is making an extensive study of the plates; Mr. WRIGHT has valuable spectroscopic observations extending throughout the apparition of the comet; numerous observations of the tail were made by various members of the staff, especially when the tail was near the Earth; and the results of all of these observations should be issued in a manner worthy of the subject and occasion.

It is characteristic of comets' tails that they curve backward from the line drawn from the Sun through the nucleus, the degree of the lagging being a function chiefly of the comet's distance from the Sun. It was expected that the tail of Halley's Comet would lag behind the line joining the Sun and nucleus to a certain extent, in which case the Earth would pass through the tail of the comet on the night of May 18th. It transpired that the tail lagged behind much more than could have been anticipated, and that the Earth did not pass centrally through the tail. It is probable that we passed through the south side of the preceding edge of the tail. No unusual phenomena were observed in this connection.

On the nights preceding and following May 18, 1910. Halley's Comet was a magnificent spectacle as viewed through the clear atmosphere of Mount Hamilton.

An interesting study of Comet *c* 1908 was made by Miss GLANCY, Fellow, based upon photographic observations secured here by herself. This comet was the most active of any comet, as to transformations in the structures of its tail, since the application of the photographic dry plate to this subject. The

comparison of photographs made on successive nights and in several cases of two photographs on the same night revealed in the clearest possible manner that the tail materials were traveling outwardly from the head, with high velocities, in response to some force or forces originating in the Sun, as required by essentially all recent theories of tail formation.

When this comet passed to the southern sky Dr. CURTIS, in charge of the D. O. Mills Expedition at Santiago, Chile, secured excellent photographs with large portrait cameras, which he had borrowed from Santiago photographers, thus extending the accurate historical record of this interesting object through several weeks.

The spectrum of this comet was likewise epoch-making. Observations obtained at Mount Hamilton and Santiago and at several other observatories brought to light an essentially new form of cometary spectrum, in that lines arranged in rhythmical pairs were given accurate observations. Professor FOWLER, of London, has since succeeded in matching this spectrum in his laboratory by light obtained electrically from rarefied carbon monoxide under certain conditions, but it has not yet been made clear why the spectrum of this comet should differ so widely from that of other similarly observed comets.

Micrometer observations of comet positions have been ob-:ned as follows:—

Comet *c* 1908	8 nights	Miss GLANCY
Comet *a* 1909	7 nights	Miss GLANCY
Comet *c* 1909	5 nights	AITKEN
Comet *e* 1909	6 nights	YOUNG
Comet Halley	14 nights	AITKEN
Comet *a* 1910	5 nights	AITKEN
Comet *b* 1910	7 nights	YOUNG

Miss GLANCY made micrometer observations for the positions of the asteroids *Juewa* (139) on four nights and of *Athor* (161) on seven nights.

Accurate positions of comets were determined from Crossley photographic plates by Dr. CURTIS on twenty nights for Comet Halley and on three nights for Comet *a* 1910.

The excellent weather prevailing during the more interesting phases of Halley's Comet enabled Dr. AITKEN to secure

on May 15th the last position observation prior to the transit of the comet's head across the Sun on May 18th, and on May 20th the first position observation following the transit, so far as published observations enable us to determine. These observations are of special value in connection with perturbations of the comet arising from its close approach to the Earth.

In the summer of 1908 Mr. FATH, Fellow, investigated the nature of the faint light which for many years had been noticed on summer nights along our northern horizon. Three hypotheses as to the origin of this light were examined: that it is an aurora; that it is a twilight arch; and that it is the Zodiacal Light. Sporadic observations of a similar nature had been made in earlier years by HERRICK, NEWCOMB, and BARNARD. It seemed fair to conclude from Mr. FATH's observations that the phenomenon is the Zodiacal Light.

The lenticular illumination of the sky, which we call the Zodiacal Light, can usually be traced east and west from the Sun, entirely across the night sky of Mount Hamilton and other good observing stations. This establishes that the materials which send the light to us are distributed approximately in the plane of the ecliptic, or of the Sun's equator, even further out from the Sun (east and west) than the orbit of the Earth. Mr. FATH's observations of the illumination above the northern horizon at midnight on fourteen nights established that the materials responsible for the Zodiacal Light extended northwardly from the Sun at least 46°, as viewed from the Earth.

These studies must be considered as merely preliminary. There is opportunity for an efficient organization of observers occupying selected observing stations in both hemispheres to obtain exceedingly valuable results as to the form and dimensions of the lenticular volume containing the Zodiacal Light, and of the variations in Zodiacal Light intensity as we proceed outwardly from the Sun. The subject is one of growing importance.

The spectrum of the Zodiacal Light was photographed by Dr. FATH in the fall of 1908 on Mount Hamilton, and in the fall of 1909 on Mount Wilson. The spectrum appeared to be a replica of the solar spectrum, in so far as could be judged from the faintness and small scale of the photographic image.

We here have strong evidence in support of the view that the Zodiacal Light is sunlight reflected from concrete particles distributed throughout the lenticular volume referred to.

The thesis of Mr. FATH, in partial fulfillment of the requirements of the degree of doctor of philosophy in the University of California, based upon the spectra of some spiral nebulæ and globular star clusters photographed with the Crossley reflector, was a successful beginning in the study of an important subject. The spectra of the spiral nebulæ are described in the text-books as continuous. Mr. FATH found that no spiral nebula investigated has a truly continuous spectrum. They vary from spectra consisting principally of bright lines, such as are found in the gaseous nebulæ, to those containing only absorption lines of the solar type. These objects appear to occupy early places in the evolutionary development of stars and the stellar system, and the investigations should be continued on a more extensive scale.

The spectrum of the great cluster of stars in *Hercules* gave evidence of containing stars of different spectral types, while two other clusters recorded spectra of the so-called F type, or the type which is believed to indicate average effective age. A spectrogram of the great nebula in *Andromeda*, of excellent density, reveals a type apparently identical with that of our Sun. It is difficult to interpret this observation, except upon the theory that this, the most prominent nebula in the whole sky, is in reality an extremely distant aggregation of stars whose processes of evolution have reached the solar stage.

The thesis of Mr. DUNCAN, Fellow, in partial fulfillment of the requirements of the degree of doctor of philosophy in the University of California, studied the orbits of the *Cepheid* variable stars Y *Sagittarii* and RT *Aurigæ*, and the possible causes for this type of stellar variation. The orbits deduced for these two stars, from spectrographic determinations of their radial velocities, confirmed the remarkable fact first announced in Dr. ALBRECHT's thesis, that the stars of this class have maximum brilliancy at the time of their most rapid approach to the observer, and minimum brilliancy at the time of their most rapid recession from the observer; in other words, that the brilliancy of a variable star of this class at any instant is a

function of the observer's position in space. Mr. DUNCAN discussed several hypotheses to explain the variations of brilliancy, but it must be said that no thoroughly satisfactory explanation has yet been presented.

The appointment of Astronomer PERRINE to the directorship of the National Observatory of the Argentine Republic, and his departure in April, 1909, necessitated several changes in our observing staff. Dr. HEBER D. CURTIS, in charge of the D. O. Mills Expedition at Santiago, Chile, was called back to Mount Hamilton, to succeed Dr. PERRINE in charge of the Crossley reflector and in other duties. Assistant Astronomer JOSEPH H. MOORE was appointed acting astronomer in charge of the D. O. Mills Expedition. The latter left Mount Hamilton in April, 1909, and assumed charge of the expedition on June 10, 1909. Dr. CURTIS returned to Mount Hamilton on August 22d.

The second period of the D. O. Mills Expedition, in immediate charge of Dr. CURTIS, extending from March 1, 1906, to June 10, 1909, was characterized by most commendable activity. The number of photographs of stellar spectra secured in this interval was approximately sixteen hundred; all of these were measured in a preliminary way and a large proportion of them definitively; Comet Morehouse, especially interesting from the unusual changes in the structure of the tail and as to its spectrum, was studied on many nights; and Dr. CURTIS took an active part in the Pan-American Scientific Congress of 1908-09, presenting one general and two technical papers on astronomical subjects.

The high standards set by Astronomers WRIGHT and CURTIS, successively in charge of the expedition, have been maintained by Acting Astronomer MOORE. The number of spectrograms secured from June 10, 1909, to July 1, 1910, was nearly nine hundred. The duties of Mrs. MOORE, assistant, have related to the measurement of the spectrograms, and the measures and reductions have almost kept pace with the observations.

The faithful services of G. F. PADDOCK, assistant astronomer, throughout the administrations of Messrs. CURTIS and MOORE should be acknowledged. An assistant to measure the plates was not employed during the second period of the expedition, and the measures were necessarily in arrears. Messrs. CURTIS

and OLIVIER have devoted a proportion of their time at Mount Hamilton to the measures and reductions. It is a great satisfaction to say that all the southern spectrograms secured up to the end of the year 1910 will have been measured and reduced by that date.

The total number of spectrograms secured at Santiago during the three administrations up to July 1, 1910, was 3,384. The total number of stars observed is 710. With a few exceptions these are all south of declination —20°. The accuracy of the resulting radial velocities of the stars is fully up to present-day standards.

The solution of the larger problems of the sidereal system is demanding that the spectrographic observations of stellar velocities be applied to as many stars as the light collecting powers of existing telescopes will permit. The D. O. Mills Expedition is fitted to secure these observations, rapidly, and with remarkable economy. Funds pledged by the late Mr. MILLS are sufficient to maintain this work only until the spring of 1911. It is hoped by astronomers in all countries, as well as by those of us immediately concerned, that the life of the expedition may be extended at least five years, or, if possible, that endowment will be available for obtaining results in perpetuity. To have the work cease next year would be a pity.

The most extensive investigations in progress at Mount Hamilton relate likewise to the spectrographic determination of stellar velocities by means of the D. O. Mills spectrograph attached to the 36-inch refractor, in accordance with the program entered upon by Mr. CAMPBELL in 1896. The spectrograms secured on this program during the biennial period are numbered from 5,318 to 6,529. Approximately one thousand stars all north of declination —30° have been observed in this manner. The observing program, as finally made, definitely includes all stars brighter than 5.01 visual magnitude, as assigned in the Revised Harvard Photometry, lying in the north three-quarters of the sky; and it is planned to secure at least four observations of each star, except for those stars whose spectra are found to contain no measurable lines. The observations of the latter will be deferred until after the completion of the remainder of the program, when dispersion lower than that of 3-prisms

will then be employed upon these stars; and, as the exposure times will be short, this supplementary program should be completed rapidly. The observing program is essentially complete for all stars accessible for summer observation. A small section of the winter sky is in arrears; but given the average number of clear nights next winter the remaining observations should be secured. Largely by virtue of assistance supplied by the Carnegie Institution of Washington, the measures and the reductions of the photographs are nearly up to date.

The total number of stars observed at Mount Hamilton and at Santiago, not counting twice those observed at both stations, is more than sixteen hundred.

The number of stars whose radial velocities are variable, under the influence of invisible companion stars, continues to increase. Twenty-five systems of this kind have been announced from Santiago and fifty-three systems from Mount Hamilton during the two years. More than fifty additional binary systems have been discovered at the two stations, and are awaiting announcement later in the present year.

Many of the stars which have been under observation at Mount Hamilton during the past ten or twelve years, which were thought to be traveling with constant speeds, are now found to be moving with variable radial velocities in orbits of long periods.

More than four hundred spectrographic binary systems have been discovered in the past fifteen years, principally by the Mills spectrographs at Mount Hamilton and at Santiago, and by the Bruce spectrograph at Williams Bay, out of not more than seventeen hundred observed stars. Thus one star in four, approximately, of those previously supposed to be single is proved to be a close double, the invisible companion in each case being of nearly the same order of mass as the primary star. The proportion is rapidly increasing, and as the observations are extended over a longer period, enabling us to detect variable velocity in the case of slowly revolving systems, we must expect that at least one star in every two or three is a spectroscopic binary. In fact, the star whose radial velocity is constant, indicating that it is not attended by a massive close companion, may be the exception and not the rule. Indeed,

it would not be surprising if our solar system, consisting of a great central Sun and a family of very small planets, should prove to be not the prevailing type of stellar systems, but an extreme type. In this connection we should note the total absence of evidence that any other star is attended by planets comparable in minuteness with the planets of the solar system.

Up to January 1, 1910, the radial velocities of 1,020 stars had been determined with the Mills spectrographs at Mount Hamilton and at Santiago, after excluding stars whose spectral lines did not admit of accurate measurement, several other stars whose deduced velocities depended upon a single observation, and those spectroscopic binary systems for which the velocities of the centers of masses had not been determined. Published velocities were available also for forty stars observed with spectrographs at other observatories and not yet observed with the Mills spectrographs. Adding the velocities for thirteen nebulæ, as obtained in 1890 by KEELER, using visual methods, there were 1,073 radial velocities available for the preliminary solution of certain fundamental problems of the stellar system. With the assistance of my colleagues, the computations for these solutions were made prior to January 20, 1909; and below are given the leading results, in outline, as they were presented in the Silliman lectures delivered in Yale University between January 24 and February 2, 1910. Lack of space prevents the quoting of details.

Assuming that the apparent radial velocity of each star was the reflex of the Sun's motion through space, and giving equal weight to each of 1,047 objects, a solution of the 1,047 resulting equations by the method of least squares assigned a speed of 17.73^{km} per second to the solar system, toward that point in the sky whose right ascension is $273^\circ.5$ and declination $+28^\circ.0$.

Another solution was made by combining the 1,047 stellar velocities into 172 groups and solving the 172 resulting equations. The deduced motion of the solar system was at the rate of 17.77^{km} per second toward that point in the sky whose right ascension is $272^\circ.0$ and declination $+27^\circ.5$.

It is expected that a more definitive solution will be made next year, and no doubt these elements obtained for the solar motion will be slightly altered.

After the effect of the solar motion upon the apparent motion of each star was eliminated, the velocities of the stars were tabulated with reference to their spectral types. The results were as follows. The letters O and B represent stars in the early stages of evolution, and M the oldest stars.

No. of Stars.	Spectral Types.	Average Velocities.
141	O and B	8.99^{km}
133	A	9.94
159	F	13.90
529	G and K	15.15
72	M	16.55
13	nebulæ (KEELER)	23.4

The number of nebulæ is entirely too small to make the result trustworthy for them, but in the first five lines of the table we have the remarkable discovery that the speed of a star in space is a function of its spectral type: new stars move slowly and old stars move relatively rapidly. It appears that the velocity of a star increases as it grows older. It is difficult to conceive that stellar velocities should vary otherwise than in accordance with the law of gravitation, each star moving under the combined attractions of all the other stellar systems in the universe, but it is not clear why the velocities should in general increase with time.

KAPTEYN discovered six years ago that the stars have a preference for motion toward and from two opposite points of the celestial sphere: one of the points being in right ascension 93° and declination + 12°. His determination was based upon the observed proper motions of stars. A half dozen confirmations were promptly published by other astronomers, basing them also upon proper motion data. Our radial velocity determinations afforded an admirable test of KAPTEYN's conclusion. If the stars are moving at random, the average velocities of approach and recession should be equal in all parts of the sky. If the stars have a preference for motion in the directions assigned by KAPTEYN, the velocities of approach and recession should be greater in the vicinity of the two points defined by KAPTEYN than in areas intermediate between these two points. I found that 154 stars lying within 30° of KAPTEYN's points have an average radial velocity of 15.9^{km} per second; that 383 stars lying in the zones 30° to 60° from these points have

average radial velocities of 14.0^{km} per second; and that 508 stars situated in the zones 60° to 90° from these points have average radial velocities of only 12.75^{km} per second. It was therefore found that the average radial velocities near KAPTEYN's points are approximately thirty-three per cent greater than the average velocities of the stars situated midway between these points. KAPTEYN's conclusions were confirmed.

The radial velocities of the stars permit us to determine the average distances of large classes of stars, though not of individual stars. Computations to this end, while highly preliminary, led to interesting conclusions.

The view had prevailed that early-type stars were further away from our position in space than are the older stars. KAPTEYN's results, for example, placed the early-type stars approximately two and a quarter times as far away from us as the older-type stars. My results do not confirm this conclusion. It is found that the stars of different spectral types are in general quite thoroughly mixed.

It was found that all classes of stars down to the fifth, and especially the brighter magnitudes, were further away than the formulæ for average distances had placed them; that is, that the scale of the sidereal universe is greater than had previously been supposed.

More complete solutions of the problems referred to, which are but a few of those resting quite directly upon our observational results, will be undertaken in the near future, when the observational data shall have been rendered more homogeneous by the completion of the program.

A systematic study of spectroscopic binary stars led to many interesting conclusions. A few of these, in brief, are:—

First, the period of revolution in a binary star is a function of the spectral type: the periods for early types are in general short and for later types in general long.

Second, the eccentricity of the orbit is a function in general of the periods of revolution and, therefore, of the spectral types: the orbits of the short-period, early-type binaries are in general nearly circular, whereas the orbits of the long-period, late-type binaries are in general very eccentric.

The orbits of about seventy spectroscopic binary systems

available at the time that the photographs were made seem to afford confirmation of the theoretical conclusions of DARWIN, POINCAIRE, and SEE concerning the origin and development of binary stellar systems.

Lick Observatory Bulletin No. 181, forming a Second Catalogue of Spectroscopic Binary Stars, lists all spectroscopic binaries discovered prior to January 1, 1910, and all orbital data available on March 15, 1910, and contains the report of my studies of spectroscopic binaries just described.

Dr. MOORE computed the orbit of the Cepheid variable X *Sagittarii.*

Mr. MERRILL computed the orbit of the spectroscopic binary *β Capricorni.*

Dr. CURTIS observed at Santiago the radial velocity of the star Córdoba Zones, $5^h.243$, whose proper motion is the largest known and found that it was receding from our solar system with an unprecedented speed of 242^{km} per second.

Mr. OLIVIER, Fellow, has utilized time spared from other duties for the discovery and measurement of double stars south of the southern limit of the Lick Observatory double-star survey. He discovered and measured forty-four pairs, and obtained several hundred observations of double stars already announced.

Mr. OLIVIER'S special interest has lain in the observation and study of meteors. He has charted 1,223 in the last year, and has computed the orbits of all for which the observational data are satisfactory.

Mr. WRIGHT studied the bright hydrogen lines in the spectrum of the variable star *Omicron Ceti,* in order to determine whether the multiple character of these lines is due to the action of magnetic forces in the star, in accordance with the phenomenon known as the Zeeman effect. He obtained no evidence of this effect.

Mr. WRIGHT is making systematic studies of the spectra of nebulæ and of various stars whose spectra contain bright lines, taking advantage of recent advances in photography to record the spectra in the yellow, orange, and red regions. A number of new nebulæ lines and stellar bright lines have been discovered in this manner.

The Rumford Committee of the American Academy of Arts and Sciences has made grants of funds to provide a Hartmann photometer, to be used in the study of polarized light in the solar corona as based upon photographs of the corona obtained by the Crocker eclipse expeditions; and to provide a quartz spectrograph for general utility in the study of celestial spectra in the ultra-violet. Both instruments are now utilized for the purposes specified, the former by Mr. YOUNG and the latter by Mr. WRIGHT.

A considerable number of minor studies by various members of the staff are not mentioned from lack of space.

The resignations of Astronomer PERRINE and Assistant Astronomer ALBRECHT to accept, respectively, the positions of director and first astronomer in the Argentine National Observatory, were recommended for acceptance with regret. Their services were exceedingly efficient. Confidence is felt, however, that their efficiency will assist in the development of astronomy in the southern hemisphere, and in removing arrears in the special lines of investigation for which the observatory at Córdoba is equipped. It is of interest to note that nine astronomers, who have been connected with the Lick Observatory, have recently spent several years in southern hemisphere astronomy, or have accepted permanent duties in the southern hemisphere. It is unavoidable that some disorganization should result from these frequent changes, but the end in view is worth the cost.

Dr. AITKEN was lecturer in the summer session of the university for the years 1908 and 1909.

Director CAMPBELL was Silliman lecturer in Yale University for the academic year 1909-10. He delivered eight lectures on the subject "Stellar Motions," with special reference to stellar motions as observed with the spectrograph.

The Janssen Prize of the Paris Academy of Sciences, consisting of a gold medal, was conferred upon Director CAMPBELL in the spring of 1910.

The director is pleased to acknowledge again the cordial support of all the members of the staff, and to express appreciation and thanks to those members of the staff who have assisted him in securing and measuring stellar spectrograms.

Respectfully submitted, W. W. CAMPBELL,

Director of the Lick Observatory.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON COMET *c* 1910 (CERULLI-FAYE).

On November 10th a telegram was received from the Harvard College Observatory announcing the following position of a new comet discovered by Professor CERULLI at Teramo, Italy, November 9.3131 Gr. M. T.; right ascension, $3^h\ 38^m\ 35^s.9$; declination, $+8°\ 43'\ 20''$.

It is customary at the Students' Observatory to compute an orbit of every new comet as soon as three observations are available. The next two observations received of Cerulli's Comet were one by EPPES (U. S. Naval Observatory) on the 11th, and one by YOUNG (Lick Observatory) on the 13th.

An attempt was made to pass a parabola through these three observations, but the computations showed that no satisfactory parabola could be passed through them. The solution was then carried forward without hypothesis regarding the eccentricity, and resulted in a short-period orbit.

The failure to represent the observations by a parabola, and the similarity of the parabolic elements i, ω, Ω, and q to the corresponding elements of Faye's Comet, led Professor LEUSCHNER to suspect the identity of Cerulli's and Faye's comets and to announce the same by telegram with our elements.

The parabolic elements are:—

$$T = 1910 \text{ November } 19.487 \text{ Gr. M. T.}$$

$$\left.\begin{aligned} \omega &= 200^\circ\ 17'.4 \\ \Omega &= 212\ \ \ 57.8 \\ i &= \ 18\ \ \ 17.1 \end{aligned}\right\} 1910.0$$

$$q = 2.1958$$

The elliptic elements are:—

$$
\begin{aligned}
T &= 1910 \text{ November } 12.413 \text{ Gr. M. T.} \\
\left.\begin{aligned}
\omega &= 206^\circ\ 20'.6 \\
\Omega &= 205\ \ \ 29.1 \\
i &= \ 10\ \ \ 14.2
\end{aligned}\right\} & \ 1910.0 \\
e &= 0.5459 \\
\mu &= 512''.34 \\
\log a &= 0.5603 \\
\text{Period} &= 6.926 \text{ years}
\end{aligned}
$$

The elements of Faye's Comet, with which the comparison was made, are those derived by STRÖMGREN for the return of the comet in 1903.

They are as follows:—

$$
\begin{aligned}
T &= 1903 \text{ June } 3.64 \text{ Berlin M. T.} \\
\left.\begin{aligned}
\omega &= 198^\circ\ 58'.8 \\
\Omega &= 206\ \ \ 28.0 \\
i &= \ 10\ \ \ 37.5
\end{aligned}\right\} & \ 1900.0 \\
e &= 0.5652 \\
\mu &= 480''.16
\end{aligned}
$$

Owing to the unfavorable position of the comet in 1903, it was not found during that apparition. According to STRÖMGREN's elements, if perturbations be neglected from 1903 to 1910, Faye's Comet should have passed perihelion October 24, 1910.

There are two methods available for the identification of comets. The first is that of comparison of the elements; the second is known as TISSERAND's criterion for the identity of comets (*Bulletin Astronomique*, 6, 289, and Méchanique Céleste, 4, 203). The equation[1] of identification in which the

$$\frac{1}{a_1} + 2\sqrt{a_1\,(1 - e^2_1)}\cos i_1 = \frac{1}{a_2} + 2\sqrt{a_2\,(1 - e^2_2)}\cos i_2$$

subscripts 1 and 2 refer to the comets that are to be compared. This relation between the two comets is necessary, but not sufficient for their identification. Calling the left-hand member of the equation C_1 and the right-hand member C_2, the numerical values for Faye's and Cerulli's comets are C_1 (Faye's) $= 3.4223$, C_2 (Cerulli's) $= 3.4186$.

[1] Moulton's Celestial Mechanics, p. 203.

It is hardly to be suspected that the accidental errors in the observations upon which the foregoing computations are based, can be such as to render accidental the agreement between our elliptic elements and those of Faye's Comet.

The comet is in a favorable position for observation, and is visible in a small telescope. Its nearest approach to the Earth was about 65,000,000 miles. Its perihelion distance is about 160,000,000 and aphelion 521,000,000 miles. When the comet is passing aphelion it is a little beyond the orbit of *Jupiter*.

It is to be noted that all of the foregoing results are based on an orbit computed from a short arc, and it is to be expected that the elements will be somewhat different for an orbit computed from a long arc. All the computations were made by Leuschner's Short Method.

W. F. MEYER,
SOPHIA H. LEVY.

BERKELEY ASTRONOMICAL DEPARTMENT, December 9, 1910.

GENERAL NOTES.

Thorvald Nicolai Thiele.—Dr. T. N. THIELE, emeritus professor of astronomy, and formerly director of the Observatory of Copenhagen, died on September 26, 1910, at the age of seventy-two years. THIELE was a student of D'ARREST, and in 1860 accompanied him to Spain in order to observe the total solar eclipse of that year. Dr. THIELE was interested in some of the practical application of mathematics and made a special study of the subject of insurance, of the theory of observations, and of interpolation. He also made contributions to the problem of three bodies and to our knowledge of double-star orbits.

Felipe Valle.—Mr. F. VALLE, director of the National Observatory of Mexico, at Tacubaya, died in the early part of September, 1910. During recent years the work of the observatory has been given over largely to work on the astrographic charts. Mr. VALLE has been a member of the Astronomical Society of the Pacific since its foundation in 1889.

Notes from "Science."—Dr. E. C. PICKERING, director of Harvard College Observatory, announces that a new star, whose approximate position is R. A. $17^h\ 32^m\ 15^s$, Dec. $-27°\ 32'.3$ (1875), was discovered by Mrs. FLEMING in the constellation *Sagittarius* on October 1, 1910. It appears on sixteen photographs taken at Arequipa with the eight-inch Bache and the one-inch Cooke telescopes, between March 21, 1910, and June 10, 1910. The magnitude has been estimated as varying from 7.8 to 8.6 between these dates. The spectrum is faint, but shows the bright hydrogen lines $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, $H\zeta$, and $H\eta$, with a trace of $H\gamma$ as dark on the edge of greater wave-length of the bright line $H\gamma$. The star does not appear on seventeen photographs taken between July 23, 1889, and October 7, 1909, although most of them show stars fainter than the twelfth magnitude and one plate shows stars of the fifteenth magnitude or fainter. An observation by LEON CAMPBELL on October 3,

1910, with the 24-inch reflector confirms the presence of this object and gives its magnitude as about 10.5.

An association for the promotion of astronomy has been formed in India. It is to be known as the Astronomical Society of India, and has its headquarters at Calcutta.

Dr. E. C. PICKERING announces that a new star, whose approximate position is R. A. $16^h\ 31^m\ 4^s$, Dec. $-52°\ 10'.6$ (1875), was discovered by Mrs. FLEMING in the constellation *Va*, on October 13, 1910. It appears on twenty-one photographs taken at Arequipa between April 4 and August 3, 1910. The magnitude has been estimated as varying from 6.0 to 10.0 between these dates. The spectrum is quite faint, but shows, on three plates, the bright lines, 5007, $H\beta$, 4670, $H\gamma$, $H\delta$, $H\epsilon$, and $H\zeta$, one of the plates showing also the bright line $H\eta$. Apparently this object had passed into a nebulous condition before its spectrum was photographed. The star does not appear on forty-four photographs taken between August 20, 1889, and March 19, 1910, although almost all of them show stars fainter than the twelfth magnitude, and two plates show stars as faint as the fifteenth magnitude.

The honorary degree of doctor of philosophy was conferred upon Dr. GEORGE E. HALE by the University of Berlin at its recent centenary celebration.

According to a cablegram to the daily papers, a ceremony in celebration of the completion of the Vatican Observatory under the direction of Father HAGAN was held in the papal apartment on November 17th. A speech was made by Cardinal MAFFI, president of the observatory, to which the Pope replied, highly commending the work of Father HAGAN.

Professor W. S. EICHELBERGER assumed the directorship of the U. S. Nautical Almanac Office on November 2d, succeeding Professor MILTON UPDEGRAFF.

NEW PUBLICATIONS.

ANDING, E. Kritische Untersuchungen ueber die Bewegung der Sonne durch den Weltraum. Zweiter Abschnitt. B. G. Teubner. Leipzig. 1910. 4°. 250 pp. Paper.

Annals of the Royal Observatory, Edinburgh. Vol. III. Catalogue of 2,713 zodiacal stars for the equinox 1900.0. Neill & Co., Bellevue. 1910. Price, five shillings. Folio. Cloth.

JACOBY, HAROLD. Rutherfurd photographs of stars surrounding η, 27, 34, γ, s, and 71-*Cygni*. Contribution from the Observatory of Columbia University, No. 28. New York. 1910. 8°. 115 pp. Paper.

Publications de l'Observatoire Central Nicolas. Série II. St. Pétersbourg. 1910. Folio. Boards.

Vol. II. Mittlere Oerter von 6,943 Sternen für 1885.0. 427 pp.

Vol. XV. Observations faites au cercle vertical. 634 pp.

Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Photographische Himmelskarte. Katalog. Band V. Wilhelm Engelmann. Leipzig. 1910. Folio. 470 pp. Paper.

Publikationen der Kaiserlichen Universitäts-Sternwarte zu Jurjew (Dorpat). Band XXII. Bearbeitung der von W. Struve am Dollend'schen Durchgungsinstrument der Dorpater Sternwarte während der Jahre 1818 bis 1822 angestellten Beobachtungen. Dorpat. 1910. Folio. 227 pp. Paper.

Minutes of the Meeting of the Board of Directors of the Astronomical Society of the Pacific, Held in the Rooms of the Society, 748 Phelan Building, San Francisco, at 2:00 P. M. on November 26, 1910.

President Fremont Morse in the chair. Other directors present were Dr. W. W. Campbell, Prof. Charles Burckhalter, Charles S. Cushing, John D. Galloway, and D. S. Richardson.

The special object of this meeting was to consider the award of the Bruce Medal of the Society, a report of which action will appear in later minutes.

A resolution was passed authorizing the Committee on Publication to have bound Volumes XXI and XXII of the Publications of the Society.

On motion of Director Cushing, seconded by Director Galloway, the secretary was instructed to confer with the Committee on Publication concerning the advisability of reducing the number of Publications printed bi-monthly from 750 to 500. The secretary was instructed to act on the recommendations of the committee.

Adjourned.

D. S. Richardson, *Secretary.*

Minutes of the Meeting of the Astronomical Society of the Pacific, Held in the Lecture Hall of the Chabot Observatory, Oakland, on November 26, 1910, at 8:00 P. M.

The meeting was called to order by President Fremont Morse, who introduced as the speaker of the evening Dr. W. W. Campbell, director of Lick Observatory.

The subject of Dr. Campbell's able address was "Some Interesting Peculiarities in the Motion of the Stars," and was illustrated with lantern slides.

After the meeting Professor Charles Burckhalter, of the Chabot Observatory, placed the equatorial of that institution at the disposition of members and their friends.

OFFICERS OF THE SOCIETY.

Mr. Fremont Morse .... *President*
Mr. George E. Hale .... *First Vice-President*
Mr. John D. Galloway .... *Second Vice-President*
Mr. R. G. Aitken .... *Third Vice-President*
Mr. D. S. Richardson .... *Secretary and Treasurer*
Mr. R. G. Aitken .... *Secretary on Mount Hamilton*

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NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first qurter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publicaion. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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